Volume LXXII Number 6

THE BOTANICAL GAZETTE

Editor: JOHN M. COULTER

DECEMBER 1921

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EDITED BY

JOHN M. COULTER

With the assistance of other members of the botanical staff of the University of Chicago

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P. 422, line 14, for microchemical read macrochemical

VOL. LXXII

P. 305, footnote, for no. 70 read no. 71

P. 314, line 7 from bottom, also in headings of tables I and III, for ruthenian read ruthenium

P. 318, table II under radish test for callose in sand, for Layer at tip read Same as in loam

VOLUME LXXII NUMBER 6

THE
BOTANICAL GAZETTE

DECEMBER 1921

OPTIMUM TEMPERATURES FOR FLOWER SEED GERMINATION[1]

GEO. T. HARRINGTON

(WITH TEN FIGURES)

The proper conditions for the germination of flower seeds is a subject upon which but little work has been published. During the spring of 1912, preliminary work was done in the seed laboratory of the United States Department of Agriculture on the temperature conditions best suited for the germination of a few of the more common flower seeds. During the winter and spring of 1913–1914, further work was done with the same species investigated in 1912, and with a few additional species. The publication of the results has been unavoidably delayed for several years. In the meantime, the recommendations included herein have been followed by the seed laboratory with good results.

The seeds included in the investigation were those of *Impatiens balsamina*, *Eschscholtzia californica*, *Iberis amara*, *Cosmos bipinnatus*, *Kochia scoparia*, *Delphinium ajacis*, *Calendula officinalis*, *Reseda odorata*, *Tropaeolum majus* and *T. minus*, *Viola tricolor*, *Petunia hybrida*, *Dianthus chinensis*, *Papaver* spp., *Portulaca splendens*, *Antirrhinum majus*, *Lathyrus odoratus*, and *Zinnia elegans*. Only a small number of samples of some kinds was included in the actual investigation. The subsequent experience of the seed laboratory, however, includes the germination of such kinds of seeds both at

[1] Report of work done while in the Seed Laboratory, United States Department of Agriculture.

the temperatures recommended and at other temperatures, and has verified these conclusions. Duplicates of one hundred seeds each were used in making nearly every germination test. In a few tests duplicates of only fifty or seventy-five seeds each were available, on account of the small size of the samples used.

Method and apparatus

The sweet pea and nasturtium seeds were tested in moist canton flannel, using two thicknesses of the flannel under the seeds and two thicknesses over them. Balsam, California poppy, cosmos, larkspur, marigold, mignonette, pansy, and zinnia seeds were tested between moist blotting papers, two thicknesses above and two below. Candytuft, cypress, petunia, pink, poppy, portulaca, and snapdragon seeds were tested on top of four thicknesses of moist blotting paper. In the tests which were made in 1914 the poppy seeds were tested both between moist blotting papers and on top of moist blotting paper.

All tests were made in standard water-jacketed copper germinating chambers, and were continued until no more seeds or only an occasional one germinated. The progress of germination was carefully watched, and all germinated seeds were counted and thrown away at frequent intervals in the tests which were made in 1912, and each day after germination began in the tests which were made in 1914.

The seeds were tested with the use of the constant temperatures 15°, 17.5°, 20°, 22.5°, 25°, 28°, and 30° C, and with daily alternations of temperature between 20° C. as the lower temperature and 28°, 30°, 31°, 32°, 35°, and 37° as the higher temperatures in the different alternations. The temperatures named as the higher temperatures in the alternations are those indicated by thermometers inserted in the tops of the chambers, and are 1° or 2° C. higher than the highest temperatures reached within the blotters or cloths in which the seeds were being tested. The alternations include some in which the seeds were kept from four to seven hours daily in a chamber which was constantly maintained at the higher temperatures, and the rest of the day in another chamber at the lower temperature; and others in which only one chamber was used,

this chamber being slowly heated during the forenoon, and cooled either slowly or rapidly as desired during the afternoon. When only one chamber was used the heating was accomplished by means of a properly adjusted gas flame below the chamber, and the cooling by means of a graduated stream of cold water in the top of the water jacket.

The species investigated may be divided into two groups: (1) those whose seeds germinate well at any constant temperature from 17.5° to 22.5° C., and also with temperature alternations; (2) those whose seeds require a temperature cooler than 20° C. for complete germination. Some of the samples in each group contained many dead seeds, or seeds incapable of germination at any temperature.

Results

Although a direct comparison between the tests made during the two periods (1912 and 1914) is impossible, the results of all the tests can best be discussed together. They will be considered from three standpoints: (1) the effect of alternating versus constant temperatures; (2) the effect of the different temperatures upon the germinating capacity; and (3) the effect of the different temperatures upon the rapidity of germination.

Alternating versus constant temperatures

All the species included in the investigation, with the possible exception of petunia, germinated as completely and as quickly with a favorable constant temperature as with any alternation of temperatures. It should be remembered, however, that taking the seeds out of the chambers to count those germinated introduced a brief change of temperature which may not have been entirely without effect. The influence of this brief temperature change, if it has any, would be greater when the germinated seeds are counted every day or two as in these experiments, than if they were counted less frequently.[2]

[2] While the use of an alternation of temperatures does not seem to be necessary for satisfactory germination of the kinds of seeds treated in this paper, it is very desirable, and in some cases imperatively demanded, with many other kinds of seeds. This subject will be treated in an article to appear shortly in the *Journal of Agricultural Research*.

It may be convenient in seed testing laboratories to use alternating temperatures in conducting germination tests of some of the kinds of seeds considered, in order to conform to methods established for use in testing the germination of other kinds of seeds. This matter will be discussed later.

GERMINATING CAPACITY

Twelve of the species studied belong in group 1. Table I shows the results, so far as total germination is concerned, of the

TABLE I

GERMINATION OF FLOWER SEEDS OF GROUP 1

SEEDS	AVERAGE PERCENTAGES OF GERMINATION										
	First series of tests*						Second series of tests*				
	No. of lots	20° C. 20°–28° 20°–30° 20°–31° 20°–32°	20°–35°	20°–37°	28°	30°	No. of lots	15°	17.5° 20° 22.5° 20°–30°	25°	30°
Balsam	1	98 to 99	98	98	98	....	3	94	94 to 98	97	98
Cal. poppy	2	62 to 70	62	62	59	....	1	72	77 to 85	74	68
Candytuft	2	74 to 80	83	70	74	62	5	79	78 to 80	78	76
Cosmos	1	80 to 85	....	80	....	....	1	....	87 to 92	....	90
Cypress	1	91 to 98	88	88	84	....	2	76	78 to 80	74	78
Marigold	....	....	....	....	....	....	4	66	62 to 64	62	38
Mignonette	2	68 to 71	72	66	62	....	3	73	66 to 71	65	61
Petunia	2	67 to 74	64	56	70	....	2	76	71 to 76	79	80
Pink	1	90 to 96	90	92	90	....	7	89	88 to 91	87	87
Portulaca	1	86 to 94	83	90	86	87	1	71	74 to 80	75	71
Sweet pea	....	....	....	....	....	....	2	84	84 to 94	84	84
Zinnia	1	90 to 94	96	91	91	....	2	79	79 to 85	78	74

*The two series of tests were entirely distinct, no lot of seeds was used in both series.

experiments with this group. Each of the twelve species germinated about equally well at any constant temperatures from 17.5° to 22.5° C., and with the temperature alternations 20°–28°, 20°–30°, 20°–31°, and 20°–32° C.

Seeds of balsam, candytuft, cypress, marigold, mignonette, petunia, pink, sweet pea, and zinnia germinated as completely at 15° C. as at warmer temperatures. Seeds of balsam, candytuft, cosmos, cypress, petunia, pink, portulaca, sweet pea, and zinnia germinated as completely at some or all of the constant tempera-

tures warmer than 22.5° C. as at cooler temperatures. Four of these, candytuft, pink, portulaca, and zinnia, germinated somewhat less completely at 30° than at 25° or 28° C. Seeds of balsam, California poppy, candytuft, cosmos, cypress, mignonette, pink, portulaca, sweet pea, and zinnia germinated as completely with one or both of the warm temperature alternations, 20°–35° and 20°–37° C., as with cooler temperatures.

TABLE II

GERMINATION OF SEEDS AT DIFFERENT TEMPERATURES

TEMPERATURE	AVERAGE PERCENTAGES OF GERMINATION								
	LARKSPUR		NASTURTIUM	PANSY		POPPY		SNAPDRAGON	
	1912 (1 lot)	1914 (3 lots)	1914 (2 lots)	1912 (1 lot)	1914 (1 lot)	1912 (3 lots)	1914 (8 lots)	1912 (1 lot)	1914 (3 lots)
Icebox	53	86	.....	.....	.....	.....	72	.....	38
15° C	.....	81	78	.....	81	.....	78	.....	66
17.5°	67	63	78	.....	87	77	75	.....	67
20°	48	28	74	46	78	70	60	48	62
22.5°	.....	1	66	.....	78	.....	49	.....	59
20°–28°	38	.....	.....	48	.....	70	.....	44	.....
20°–35°	34	.....	.....	48	.....	70	.....	52	.....
(cooled rapidly)									
20°–31°	29	.....	.....	.....	.....	.....	.....	.....	.....
20°–30°	25	8	65	56	74	66	52	46	52
20°–32°	11	.....	.....	45	.....	58	.....	48	.....
20°–30°	.....	.....	.....	48	.....	51	.....	48	.....
(cooled slowly)									
20°–37°	7	.....	.....	36	.....	44	.....	48	.....
25°	.....	.....	60	.....	62	.....	.....	.....	.....
28°	.....	.....	.....	39	.....	26	.....	36	.....
30°	.....	.....	7	.....	28	.....	6	.....	19

Seeds of larkspur, nasturtium (2 species, 1 sample each), pansy, poppy (a number of species), and snapdragon belong to group 2, which germinated most completely at a temperature cooler than 20° C. In 1914 the larkspur, poppy, and snapdragon seeds were tested in an icebox in which the average temperature was about 8° C., as well as with the temperature conditions used with the other kinds of seed.

Table II shows the average percentages of germination of seeds of group 2 under the different temperature conditions, arranged in the order of increasing average temperature of the germination

blotters, regardless of the highest temperature reached in the different alternations.

Pansy seeds germinated more completely at 17.5° than at 15° C.; larkspur and poppy more completely at 15° than at 17.5°; while with nasturtium and snapdragon seeds there was no difference between these two temperatures. Although the larkspur seeds tested in 1914 germinated even more completely in the icebox than at 15° C., the slowness of germination in the icebox makes the use of so low a temperature undesirable. Furthermore, the difference in total germination in favor of the icebox temperature was only with one lot of seeds, the other two germinating practically the same as at 15° C.

The rather poor samples of pansy and snapdragon seeds which were tested in 1912 germinated more completely with an alternation of temperatures than with a constant temperature of 20° C. These samples were not tested with the cooler constant temperatures which proved most favorable in 1914. The decrease in the average percentage of germination with rise in temperature above the optimum was rapid in the case of larkspur, somewhat slower in the poppy, and slow and gradual in nasturtium, pansy, and snapdragon. The low optimum temperature for germination of larkspur and poppy is reflected in the recognized practice of sowing these seeds in the fall or very early in the spring, when the ground is cold. It is significant, too, as showing the adaptation of the seed to the general physiology and life history of the plant, that poppies fail to make satisfactory growth if started after the advent of warm weather when the soil temperature is above the optimum for germination of poppy seeds. In the case of larkspur and poppy, there was a great deal of variation in the relation of temperature to completeness of germination between even the different lots of the same kind of seeds. These two species will be considered separately in the following pages.

TEMPERATURE REQUIREMENTS FOR GERMINATION OF LARKSPUR SEED.—Fig. 1 shows graphically the contrast in response to different temperatures of two different lots of larkspur seeds, tested simultaneously in 1914. Each of the three lots tested in 1914 germinated much more completely in the icebox than at 17.5° C. Fig. 2 shows the total percentages of germination of one lot of

larkspur seeds with the different temperature conditions used in 1912. The different alternations are arranged from left to right

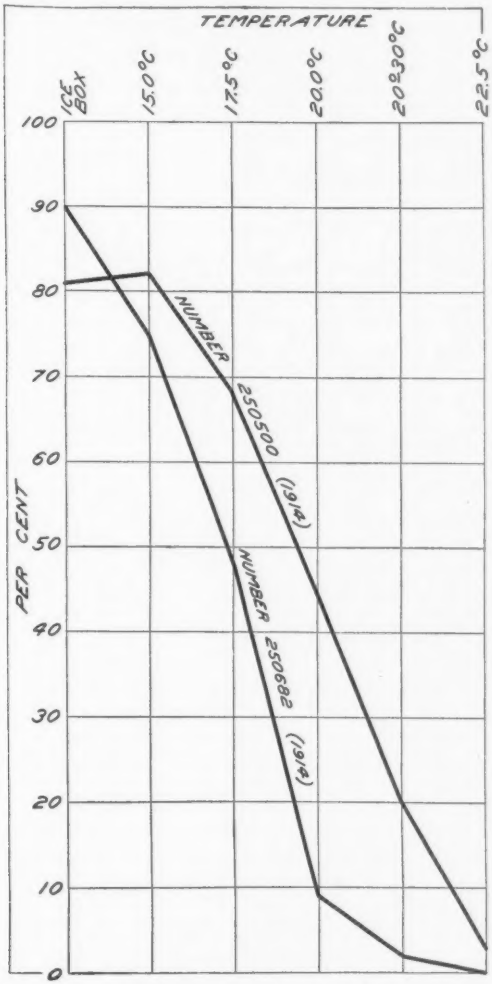


FIG. 1.—Germination of two lots of larkspur seeds

in the order of increasing mean temperature in the blotters. The percentage of germination decreased regularly as the temperature

at which the germination test was made increased from 17.5° to 28° C. The percentage of germination was 14 per cent less in the icebox than at 17.5° C., but greater than at any temperature warmer than 17.5° C. No record was kept of the temperature

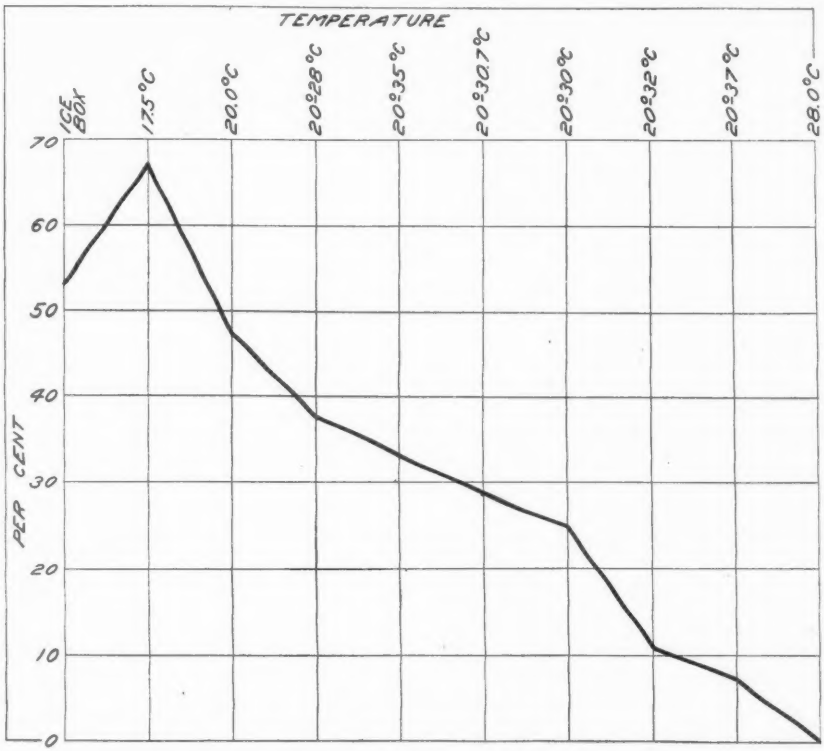


FIG. 2.—Germination of one lot of larkspur seeds

in the icebox, but it was probably cooler than in 1914, when each of the three samples tested showed a higher percentage of germination in the icebox than at 17.5° C.

TEMPERATURE REQUIREMENTS FOR GERMINATION OF POPPY SEED.—One lot of poppy seeds used in the investigations in 1912 was of the opium poppy, *Papaver somniferum*, the other two lots

were not determined as to species. In 1914 three lots of seeds of *Papaver somniferum*, three lots of the horticultural variety "Shirley" of *Papaver rhoeas*, and two lots of an undetermined species were used. Table III gives the percentages of germination of the eight lots which were tested in 1914. In general, the seeds of *Papaver somniferum* were much less sensitive to temperature conditions than were the seeds of the other species. Fig. 3, constructed from the averages in table III, illustrates the relation of temperature to completeness of germination of the three species of *Papaver* included in the tests of 1914. Fig. 4 shows the differ-

TABLE III

GERMINATION OF DIFFERENT SPECIES OF POPPY AT DIFFERENT TEMPERATURES

TEMPERATURE	PERCENTAGES OF GERMINATION										
	Papaver somniferum				Papaver rhoeas var. "Shirley"				Papaver sp.		
	No. 5440	No. 250482	No. 250768	Averages	No. 250224	No. 250693	No. 250752	Averages	No. 250196	No. 250197	Averages
Icebox	55	78	87	73	58	76	76	70	56	88	72
15° C	70	79	94	81	58	88	81	76	62	90	76
17.5°	65	78	88	77	58	78	81	72	61	90	76
20°	66	78	78	74	44	38	36	39	48	90	69
20°–30°	52	76	64	64	38	22	21	27	54	88	71
22.5°	58	78	64	67	28	39	16	28	24	84	54
30°	10	26	6	14	1	0	2	1	0	1	1

ences in germination of three lots of seed of *Papaver somniferum* with different temperatures. The temperature alternation 20°–30° C. represents a mean temperature in the blotters of practically 22.5° C. The equivalent value of these two temperature conditions for the germination of larkspur and poppy seeds is evident from the results.

GERMINATION OF POPPY SEED BETWEEN BLOTTERS AND ON TOP OF BLOTTERS.—As previously stated, poppy seeds were tested in 1914 both on top of and between double thicknesses of moist blotting paper. In the icebox the average percentage of germination on top of blotters was sixty-seven, between blotters seventy-three. At 15° C. the average percentages were respectively eighty and seventy-five. In the tests with each of the other temperature

conditions, the average percentages of germination on top of blotters and between blotters differed from each other by less

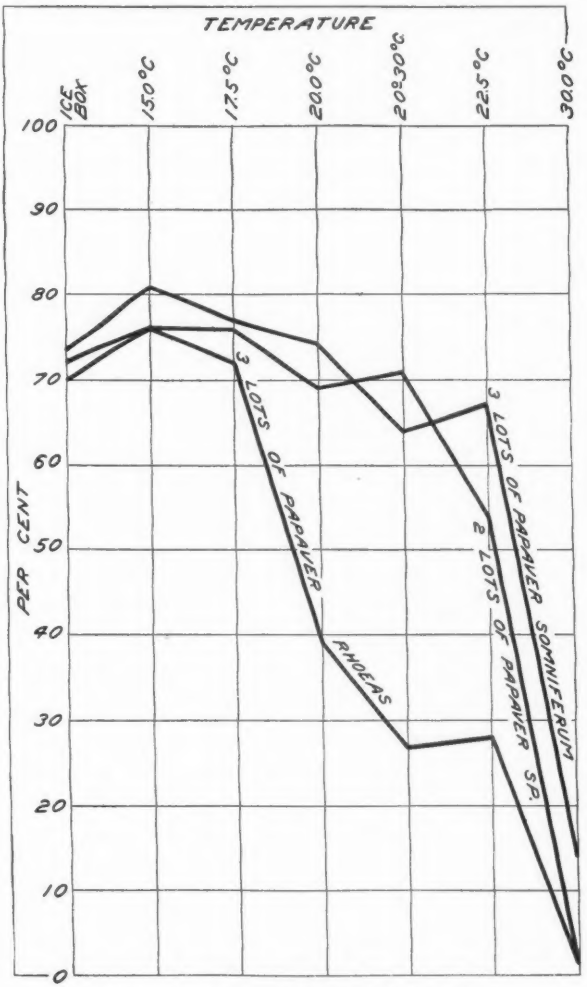


FIG. 3.—Germination of three species of *Papaver*

than 2 per cent. Averaging the results of the fifty-six tests (seven tests of each of eight lots of seeds) on top of blotters, and fifty-six

between blotters, gives fifty-five as the average percentage of germination in each case. There is, then, no advantage in either

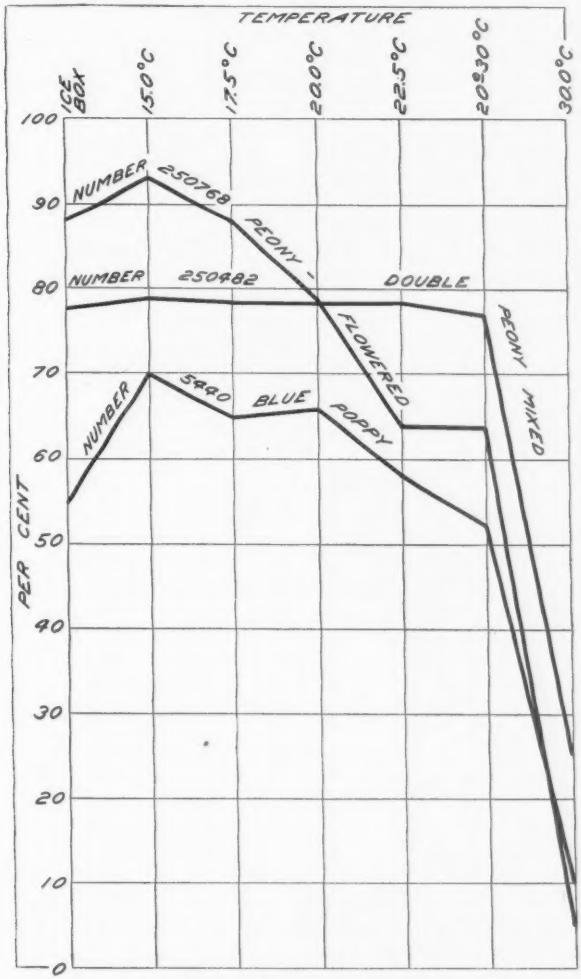


FIG. 4.—Germination of three lots of *Papaver somniferum*

method from the standpoint of completeness of germination. The position of the seeds, however, did affect the rapidity with

which germination took place in the icebox, as will be shown in the following section.

RAPIDITY OF GERMINATION

Under favorable temperature conditions, five days were required for germination tests of balsam and cypress seeds; six days for cosmos, marigold, pink, portulaca, and zinnia; eight days for California poppy, candytuft, mignonette, and opium poppy (*Papaver*

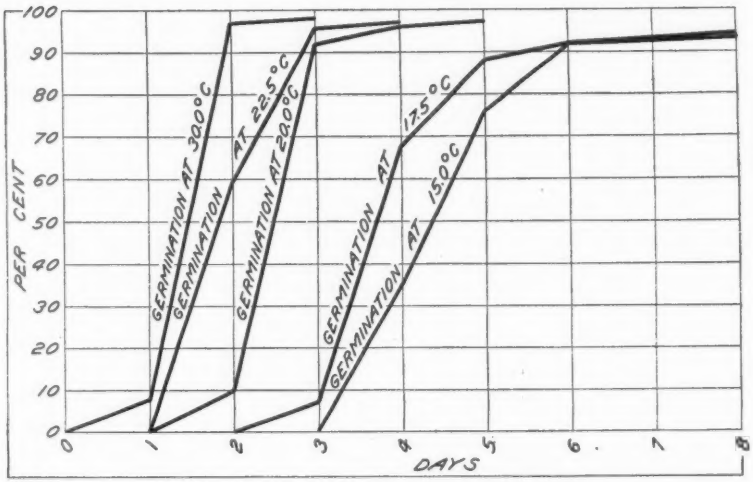


FIG. 5.—Average rate of germination of three lots of balsam seeds

somniferum); ten days for nasturtium, other species of poppy, petunia, snapdragon, and sweet pea; twelve days for pansy; and fifteen days for larkspur. For the germination of strong rapidly germinating lots of seeds, less than the number of days indicated is required. On the other hand, sometimes a very poor lot of seeds or a lot which, although producing vigorous seedlings, germinates slowly, may continue to germinate gradually for a few days longer than indicated. The warmer the temperature within the limit for complete germination, the more rapidly germination took place. A decrease of a few degrees from any given temperature usually retarded germination more than an increase of the

same number of degrees hastened it. This dependence of the rapidity of germination upon temperature was much more marked with some kinds of seeds that with others. Figs. 5–8 show the average rates of germination at different temperatures of a number of different lots each of balsam, cypress, snapdragon, and larkspur

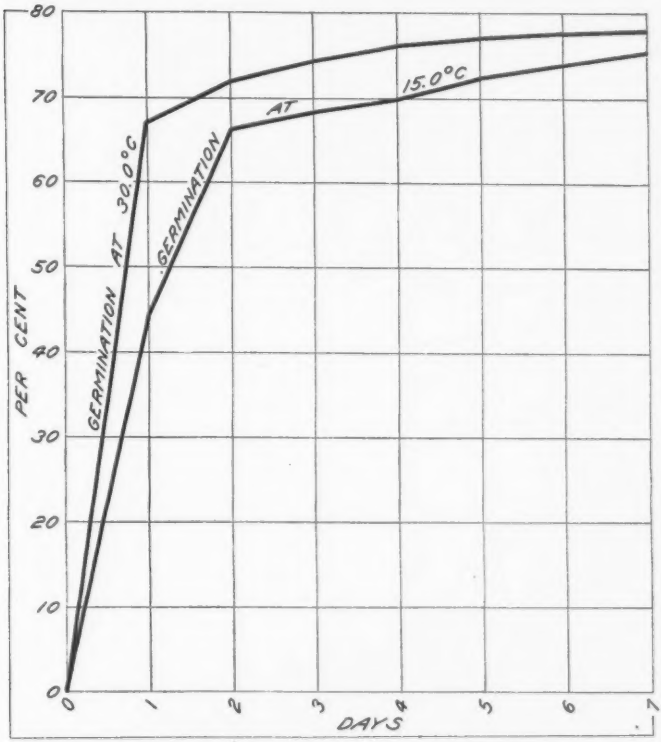


FIG. 6.—Average rate of germination of two lots of cypress seeds

seeds, and illustrate differences in sensitiveness to temperature conditions. Fig. 5, for balsam, is typical also for mignonette, petunia, and portulaca, in so far as the range of temperatures for complete germination is the same. Cypress seeds (fig. 6) germinated more rapidly than any other kind, and almost as rapidly at 15° as at 30° C. Fig. 7, for snapdragon, is typical also for

nasturtium, pansy, and poppy seed. It shows an acceleration of germination by temperatures which were above the maximum for complete germination. In contrast with fig. 7, fig. 8 (for larkspur) shows a retardation of germination as well as a great reduction in total germination by a temperature only 5° C. above the optimum for complete germination.

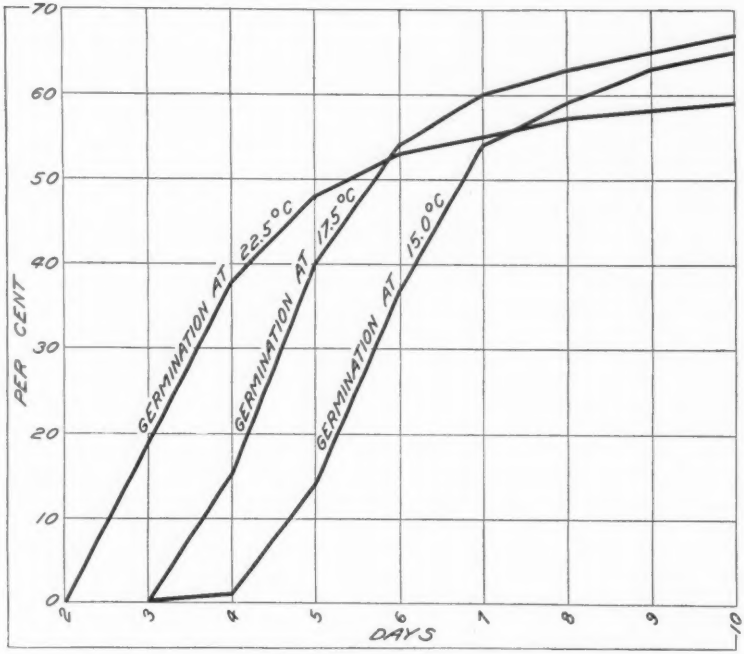


FIG. 7.—Average rate of germination of three lots of snapdragon seeds

The harmful effect of a high temperature on the germination of nasturtium, pansy, poppy, and snapdragon seeds is shown by the fact that all of these seeds germinated more slowly even during the first few days with the temperature alternation 20°–30° C. (not shown in fig. 7, but about equivalent in average temperature to 22.5° C. constant) than at temperatures lower than 22.5° C. Pansy and poppy seeds germinated even less rapidly at 20°–30°

than at 17.5° C. Exposure to 30° for only a few hours each day, therefore, had a retarding effect on germination even during the early days of the test.

A few cases of apparent influence of temperature upon germination require special mention. California poppy seeds germinated much more rapidly and somewhat more completely when the chamber was heated to 30° and allowed to cool very slowly to room temperature than with any of the other conditions of either

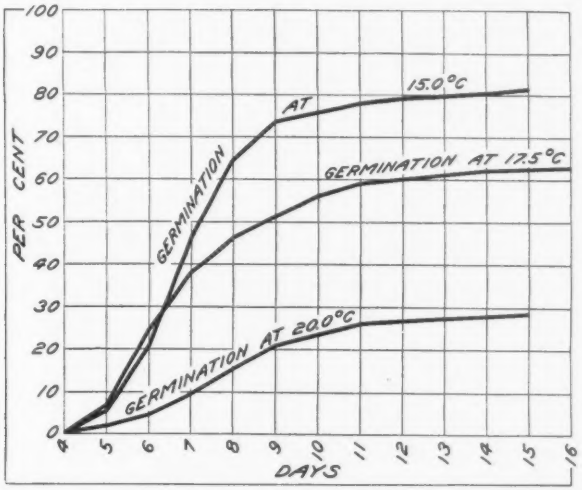


FIG. 8.—Average rate of germination of three lots of larkspur seeds

constant or alternating temperatures used in the series of tests made in 1912.

The cypress seeds were infected with a "damping-off" organism, which destroyed some of the germinated seeds almost as soon as germination began in the tests which were conducted at high temperatures. Some of the nasturtium seeds were badly infected with organisms of decay and with parasitic nematodes, which affected germination more seriously at the higher than at lower temperatures. To avoid difficulties of this kind, so far as possible all sorts of seeds should be tested at temperatures as low as are

consistent with the nature of the seeds in any given case. It is possible also that effective sterilization of the seeds before placing them in the germinator in some cases would alter the conclusions as to optimum temperatures for germination.

The two lots of petunia seeds tested in 1912 germinated somewhat less completely with either of the constant temperatures 20° or 28° than with certain of the alternations of temperatures, especially 20°–30° C. The petunia seeds used in the tests which were made in 1914, however, germinated as completely with any constant temperature from 17.5° to 30° as with the temperature alternation 20°–30° C. In these tests the highest percentage of germination obtained occurred with the constant temperatures 25° and 30°. In testing petunia seeds for germination, probably the most uniformly good results would be obtained with a constant temperature not warmer than 25° or cooler than 22.5°, or with the temperature alternation 20°–30° C.

From 4 to 10 per cent of the sweet pea seeds remained hard at the expiration of the germination tests at different temperatures. No effect of temperature upon the softening and germination of these seeds was noticed.

RAPIDITY OF GERMINATION IN ICEBOX.—In the icebox the first larkspur seeds germinated during the tenth day, the first poppy seeds during the sixth day, and the first snapdragon seeds during the twelfth day. With each kind of seeds, the progress of germination in the icebox was slow. Four weeks were required for a germination test of one lot of larkspur, and three weeks for a germination test of the other two lots of larkspur and some of the lots of poppy. The snapdragon seeds were kept in the icebox over five weeks. At the end of this time germination had practically ceased, but the total percentage of germination (38 per cent) was still but little more than one-half as great as 17.5° C. (67 per cent). The majority of the snapdragon seeds which germinated in the icebox germinated between the twentieth and thirtieth days of the test.

The germination of larkspur no. 250585 began on the eleventh day and was complete in twenty days. At the same time no seeds of larkspur no. 250500 germinated until the nineteenth day,

and germination of this lot continued through the thirty-first day. The rates of germination of these two lots of seeds in the icebox

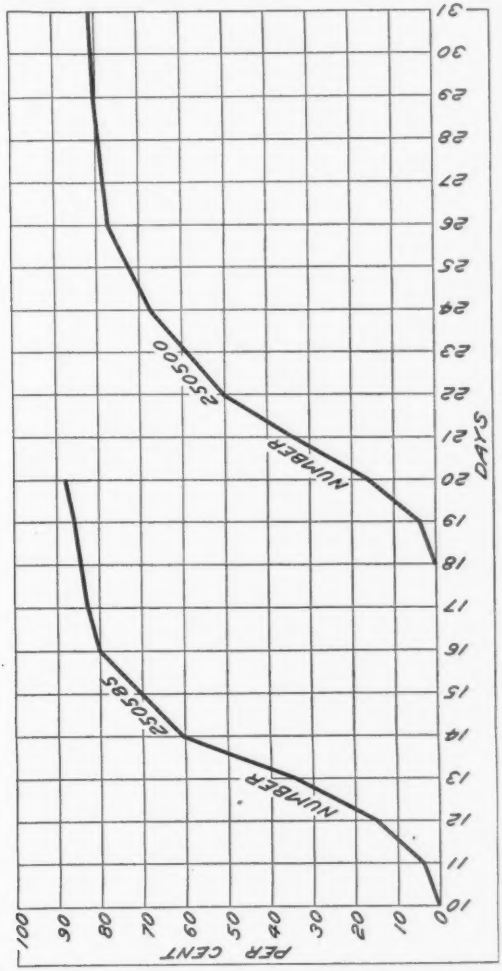


FIG. 9.—Rates of germination of two lots of larkspur seeds in icebox

are shown graphically in fig. 9. Similar but less striking differences occurred in the rates of germination in the icebox of different lots of poppy seeds of each of the three species tested.

RAPIDITY OF GERMINATION BETWEEN AND ON TOP OF BLOTTERS.—In 1914 the poppy seeds were tested simultaneously on top of blotters and between blotters. Except in the icebox, the position of the seeds did not affect the rapidity of germination. In the icebox *Papaver somniferum*, two lots of *P. rhoeas*, and one lot of the undetermined species germinated much more rapidly between blotters than on top of blotters, while there was no difference with the other two lots. The greatest difference was with

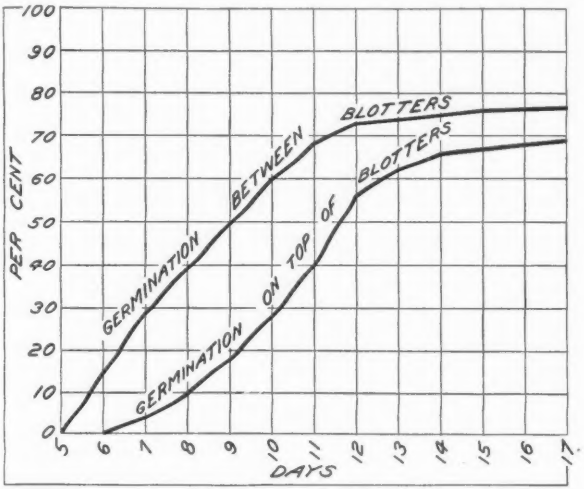


FIG. 10.—Average rates of germination in icebox of six lots of poppy seeds, between blotters and on top of blotters.

one lot of *P. somniferum*, only 5 per cent of which germinated in the first seven days when on top of blotters, in contrast with 51 per cent between blotters. As the temperature of the icebox was very cool, the further reduction of temperature on the surface of the blotters by evaporation probably was sufficient to retard the germination of these lots, and also may explain the lower total germination on top of the blotters. Fig. 10 shows the average rates of germination in the icebox of the six lots of poppy seeds which germinated more rapidly between blotters.

Discussion

It is evident from the foregoing facts that the use of warm temperatures usually increases the rapidity of germination of the species investigated, but that comparatively low temperatures are more favorable for completeness of germination. In conducting germination tests of each species, a temperature should be used which is warm enough to accelerate the progress of germination as much as can safely be done. At the same time, it should not be warm enough to prevent the germination of any viable seeds, or to encourage more than is necessary the development of microorganisms.

When the germination temperature is too warm, frequently the germinated seeds make but little growth, and it is impossible to judge the comparative vigor of different lots of seeds. Sometimes weak seeds of little value will germinate when a warm temperature is used, and will then appear to as good advantage as other strong vigorous seeds. If the germination tests are made with a more favorable temperature, both the strong and the weak seeds will germinate, but in this case the difference will be obvious at once. In this case some seedlings make rapid vigorous growth and are normal in appearance, while others have a watery translucent appearance, grow very slowly, and sometimes have begun to decay before emerging from the seed coat. On the other hand, too cool a temperature decreases the germination, increases the time required, increases also the difference in time required by different lots of seeds of the same species, and thus makes uniform procedure with the different lots impossible. This condition is well illustrated by larkspur samples no. 250500 and no. 250585 (fig. 9).

In conducting germination tests of some of the kinds of seeds, considerable latitude is permissible in deciding upon the temperature to be used. With certain other kinds, as larkspur, the temperature requirements for completeness and rapidity of germination fall within narrow limits.

The substratum should be such as to furnish abundant water to the germinating seeds without limiting the supply of oxygen. For this purpose folded blotting paper well moistened with water

is favorable. Most seeds of medium size can safely be tested between folds of blotting paper. Very small seeds do not hold the separate folds of the blotting paper apart so as to allow circulation of air between them. To insure a sufficient supply of oxygen, such seeds should be tested on top of the moist blotting paper. Candytuft seeds were tested on top of the blotting paper, not because of their size, but because of their mucilaginous covering, which softens when the seeds are wet and sticks the seeds insecurely to both the upper and lower layers of the blotting paper, thus increasing the danger of loss or displacement of the seeds when the blotters are opened to count the germinated seeds. Pansy seeds have a mucilaginous covering similar to the covering of candytuft seeds and may well be tested on top of blotting paper, instead of between blotters as in this investigation. Large seeds, such as sweet pea and nasturtium, should be tested between folds of moist canton flannel or other similar material, instead of in moist blotting paper, because the cloth folds around each seed and supplies moisture to a larger portion of its surface than the blotting paper does.

The seeds should be carefully distributed upon the substratum so that no two seeds touch each other. This guards against the spread of microorganisms, and is of special importance with seeds which are infected with such organisms as those which cause the "damping-off" of seedlings.

Table IV shows the conditions which are recommended for use in making germination tests of the kinds of flower seeds included in the investigation, and the number of days necessary for a preliminary estimate of the germinating capacity and for complete germination. The time allowed for preliminary estimate of each kind is the number of days required for the germination of approximately three-quarters (actual proportions in this investigation varied from 0.7 to 0.9) of the seeds of that kind which are capable of germinating under the conditions indicated. The temperatures given are those which it is thought will give best results with each kind of seeds when both completeness and rapidity of germination are considered. With many lots of seeds germination will be com-

plete in fewer days than are indicated for the completion of the test, and perhaps in exceptional cases a few days longer will be necessary.

Petunia seeds are the only kind for which an alternation of temperatures is recommended, although sweet peas also will germinate as well at 20°–30° C. as with a constant temperature.

TABLE IV

CONDITIONS RECOMMENDED FOR USE IN MAKING GERMINATION TESTS

SEEDS	SUB-STRATUM	TEMPERATURE	NO. OF DAYS FOR	
			Preliminary estimate	Complete test
Balsam	BB*	20° C.	3	5
California poppy	BB	20°	3	8
Candytuft	TB	20°	3	8
Cosmos	BB	20°	3	6
Cypress	TB	20°	2	5
Larkspur	BB	15°	8	15
Marigold	BB	20°	3	6
Mignonette	BB	20°	4	8
Nasturtium	C	17.5°	7	10
Pansy	TB	17.5°	6	12
Petunia	TB	20°–30° or 22.5° C †	5	10
Pink	TB	20°	2	6
Papaver somniferum	TB	15°	4	8
Other poppies	TB	15°	5	10
Portulaca	TB	20°	3	6
Snapdragon	TB	17.5°	6	10
Sweet pea	C	22.5° or 20°–30° †	5	10
Zinnia	BB	20°	3	6

* Letters used in this column indicate: BB, between blotters; TB, top of blotters; C, cloth (canton flannel).

† Either temperature condition may be used, but 20°–30°C. is probably preferable for petunia.

Petunia seeds will germinate almost as well, and frequently quite as well with the constant temperature 22.5° or 25° C. as with the alternation 20°–30° C., and either of these constant temperatures may be used for approximate results when it is inconvenient to maintain the two temperatures 20° and 30° C. Nasturtium, pansy, and snapdragon seeds will germinate about as completely (although more slowly) with the constant temperature 15° as 17.5° C. These kinds may be tested also at 20° C., although a

lower temperature is somewhat more favorable. Such considerations make it possible to test all the kinds of seeds investigated with approximately optimum conditions by maintaining only three different temperatures. These three temperatures may be either 15°, 20°, and 22.5°, or 15°, 20°, and 30° C., according as petunia and sweet pea seeds are to be tested with a constant temperature (22.5°) or with an alternation of temperatures (20°–30° C.). It should be emphasized, however, that probably more uniformly good results would be obtained by using for each species the temperature indicated in table IV.

GREENWICH, CONN.

SUBTERRANEAN ORGANS OF BOG PLANTS

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 288

FRED W. EMERSON

(WITH ELEVEN FIGURES)

Introduction

There has been much research on the subterranean organs of plants from many standpoints. The analytical study of these organs as they grow in nature, however, has chiefly been limited to comparatively recent work. In 1899 and 1900 HITCHCOCK (4) published results of work done on the Kansas flora, in which were brief descriptions of the underground parts of a considerable number of native plants, with notes on habitat and length of life. CANNON (1, 2) in 1911 and 1913 added greatly to our knowledge of the behavior of roots in the soil, showing that some of the current ideas have at best been incomplete, and that in the desert there is a wide variation in root behavior. More recently a number of papers have appeared adding information about the root and rhizome systems in a variety of habitats. Among them are papers by HAYDEN (3), MARKLE (6), PULLING (7), and WEAVER (9, 10).

The present paper deals with work carried on in an attempt to discover, first, the exact behavior of the underground parts of plants growing in peat bogs, and to some extent to compare these organs with those of the same species growing in mineral soil; and second, to determine as far as possible the factors involved in any peculiarities in behavior noticed.

While there are many references in the literature to the comparatively shallow roots in swamp lands, it seems that no one has gone into detail in determining just how shallow the roots and rhizomes are, nor with a few exceptions have the biological relationships of these parts been analyzed. YAPP (12) has described some of the relationships of roots and rhizomes in the fen, and SHERFF (8), in his analysis of the subterranean organs in Skokie Marsh,

has gone into somewhat greater detail. In neither of these papers, however, is work reported on the typical peat bog plants.

The main station for this study was Cedar Lake, at Lake Villa, Lake County, Illinois. Supplementary work was carried on in bogs at Miller and Hillside, Indiana, and in a fen at Wolf Lake, Indiana. Cedar Lake is located about five miles south from the Wisconsin line and twenty-two miles west from Lake Michigan. It is situated in the Valparaiso morainic system (5) in a considerable depression in the drift. The western border of the lake is deep and is covered by a floating mat of fibrous peat, while the north and east sides are shallow, and the vegetation passes from the usual hydrophytic forms in the water to shrubs, sedges, and grasses on the shores. This gives opportunity for comparing certain species as they grow in both peat and mineral soils, but with other conditions as nearly the same as is possible to find them in nature. The bog under consideration is of crescent form, fringing the west end of Cedar Lake, and is about 200 m. in width at its widest part. It is composed of a floating mat of peat that is only slightly decomposed, except where it comes in contact with the clay basin at its landward margin. Here it has decayed, forming a hummocky black soil. Judging from its small size, the fact that it has made but a beginning in covering the lake although it is evidently making measurable progress, and the absence of all trees with the exception of a few young tamaracks, it seems evident that this bog is geologically very young. When compared with the vegetation of other bogs of the region, the plant life of this bog is obviously in the very early stages of plant successions, and it is inconceivable that it dates back to glacial times. Thus the supposition that all bogs are relicts from the glacial period seems less plausible.

Field study

In order to determine the exact form and physical relationships of the roots and rhizomes of bog plants, the preliminary work undertaken was the mapping of these parts *in situ*. The organs in question, some of which were very tender, were followed with the finger tips and then laid bare by the removal of all the material above them. Careful measurements were taken and the maps were made

to scale on coordinate ruled paper (figs. 1, 3, 4, 6). In this work it soon became evident that, with the exception of a few species, living plant parts were very rare below a certain comparatively slight depth, and that each species had its own characteristic range of depths. In most cases the roots and rhizomes maintained almost the same level throughout their length. Hence in mapping it was necessary to show only the horizontal arrangement of the organs in question, stating the depth from the surface or the relation to the water table. Since the mat is held up by its own buoyancy, the surface remained at practically the same level

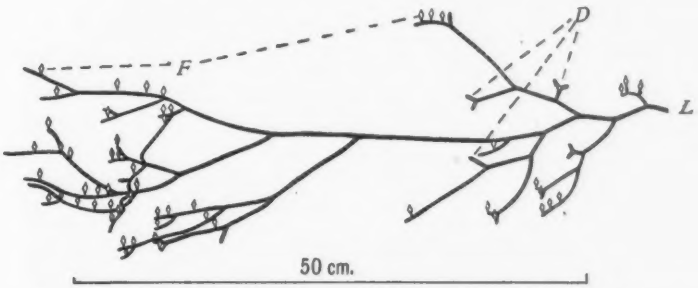


FIG. 1.—*Aspidium Thelypteris*, map of rhizome system: *L*, living attachment to older part of system; *D*, dead tips of rhizomes; *F*, foliage leaves; solid black lines, living rhizomes; note numerous dead rhizome tips, represented by cross lines on white ground, in older parts; dying behind the dichotomous branches leaving them independent is a very common means of multiplication in this fern; depth 4–6 cm.

throughout its extent and throughout the growing season. This distance from soil surface to water table was approximately 6 cm. As may be noted in the maps, the underground parts of bog plants are remarkably straight when compared with those of upland plants. Doubtless this is largely because of the lack of mechanical interference to the growing parts by the spongy peat. The more important species represented in this bog are as follows.

Sphagnum.—This plant grows abundantly over most of the floating mat, especially toward the lakeward margin. It was found to be propagating vegetatively by growing above and dying below. No other means of propagation was found. It appeared to remain alive to a depth of 3–4 cm.

Aspidium Thelypteris.—This species was studied in both bog and swampy mineral soil. The rhizomes were found to be always horizontal. The depth was 2–6 cm. in bog soil, and 1–6 cm. in mineral soil. In no case were living parts found below water. The roots were almost horizontal when near the water table, but nearly vertical and going down to 15–17 cm. deep in a substratum that was only moist. No difference of any sort was apparent in peat and mineral soil. Fig. 1, which is a map of most of the rhizome

FIG. 2.—*Larix laricina* with roots showing horizontal position; inset, young seedling and plant three or four years old showing tap root becoming horizontal; maximum depth 6 cm.

system of one plant, shows that in the older parts there are numerous dead rhizome tips and few leaves, while in the younger parts the plant is vegetating very freely. The older parts were much discolored and too brittle to trace farther than is shown in the map.

Larix laricina (fig. 2).—The larch had no tap root, all the roots being horizontal and above the water level, except where the weight of the tree forced them deeper into the peat. All living roots were 6 cm. or less in depth. There were only a few dozen comparatively young larches in the bog in question. No other tree species was found.

Typha latifolia.—The rhizomes of this species assume about the same depth in mineral or peat soil. Those measured varied from 15 to 30 cm. deep in peat, and from 12 to 25 cm. deep in mineral soil. The roots extended diagonally or vertically downward. The deepest extended far below water in both types of soil. A few of the vertical roots were found exceeding 60 cm. in depth. On account of the turbid water they could not well be followed to a greater depth.

Sagittaria latifolia.—This species is not very common in the bog, but is included because it also grows outside of the bog and affords opportunity for comparison in the two habitats. While there is considerable variation in the depth of various parts of a given

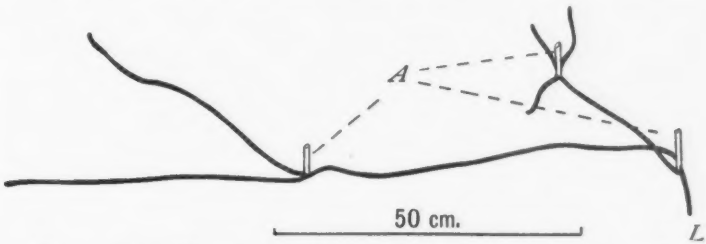


FIG. 3.—*Carex filiformis*, map of rhizome system: *A*, aerial stems; *L*, living attachment to older rhizome; solid black line, living rhizome; depth 8 cm. at aerial stems and going down to 30 cm. between aerial parts.

rhizome system, corresponding parts were found to assume about the same depth in various soils. The aerial parts arise from the rhizome at about 4–6 cm. deep, while at other places the rhizome gradually descends to depths of 10 cm. or more. The root behavior is almost identical with that of *Typha latifolia.*

Scirpus validus.—The rhizomes assumed a depth of 12–15 cm. in all soils where the species was found. A few of the roots extended downward to a depth of 30–40 cm. Nearly all of the roots were vertical, hence the entire subterranean system was below water. This bulrush was fairly common along the lakeward margin of the bog as well as in fens.

Carex filiformis.—This sedge was found in the bog only. Its roots and rhizomes varied in depth from 5 to 30 cm. The roots were approximately horizontal (fig. 3).

Pogonia ophioglossoides (fig. 4).—While this orchid plays no pronounced part in the building of the bog, it is included on account of the peculiar character of its subterranean system. This is made up of a simple but comparatively extensive root system from which the aerial parts grow. This plant has no rhizome, although the root behaves in a manner similar to a rhizome and forms an effective means of vegetative propagation. Branches proper are lacking in the roots, but one or two new roots are likely to arise adventitiously from the base of each aerial shoot. This entire root is 5–6 cm. deep, which is just at the surface of the water in the bogs studied.

Calopogon pulchellus.—In contrast with *Pogonia*, this orchid has very little root system, the chief underground part being a small bulb. The bud of this bulb frequently divides, making two

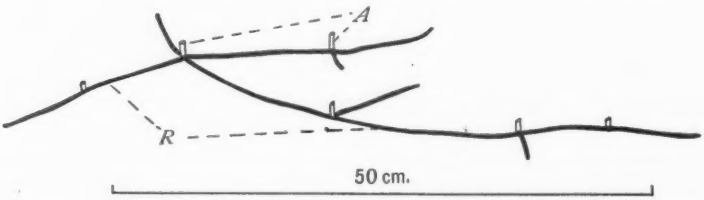


FIG. 4.—*Pogonia ophioglossoides*, map of root system: *A*, aerial stems; *R*, root; plant propagated by roots instead of rhizomes as usual in most bog plants; depth 6 cm.

new plants, which, however, are likely to remain attached to each other, hence this is a poor means of disseminating the species. The few simple roots and the bulb structures were found to be dead at about 6 cm. deep, hence no living parts were found below the water.

Betula pumila.—The dwarf birch grows obliquely or vertically upward, putting out roots at various levels in the peat. These roots assume an approximately horizontal position. They were found at various levels from 6 to 18 cm. deep.

Sarracenia purpurea (fig. 5).—This species has a vertical stem, and distorted, usually vertical adventitious roots growing out wherever the stem is covered with peat. All structures die at the water surface.

Drosera rotundifolia.—This plant behaves similarly to *Sarracenia*, except that its living parts do not extend deeper than 2 or

3 cm., and there are not more than three or four feeble, unbranched roots living at any time. Although a comparatively small plant, it appears to be able to grow upward rapidly enough to keep from being covered by the *Sphagnum* in which it often grows.

Lathyrus palustris (fig. 6).—The rhizomes and roots are horizontal in this species, and were not found living below water. The rhizomes were mostly about 5 cm. deep. The roots were few in number, short, and only slightly branched. Those around the aerial stems had numerous large tubercles containing bacteria.

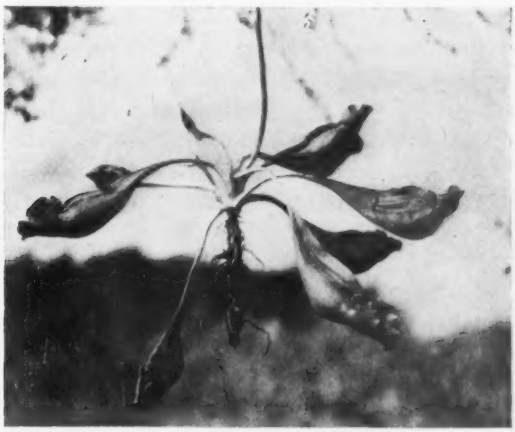


FIG. 5.—*Sarracenia purpurea*, entire root system; stem and roots dead below depth of 6 cm.; roots in normal position.

Decodon verticillatus.—This species is the most prominent pioneer extending the floating mat out over the lake. Wherever the stems come in contact with water, large amounts of cortical aerenchyma form and numerous adventitious roots grow down. Considerable quantities of peat cling to this mass of stems and roots, and thus a floating substratum is formed on which other plants soon begin to grow. Among the most common of these are *Sphagnum*, *Aspidium*, and *Scirpus*. The greatest depth to which the roots of *Decodon* descend in the water was not determined accurately, but it was found that they attain at least a depth of more than 40 cm.

Vaccinium macrocarpon.—Where the prostrate stems of the cranberry come in contact with the moist peat, numerous short adventitious roots appear growing diagonally downward or almost horizontal. As the peat forms above and the roots and stems are weighed down to the water level, they die at the surface of the water. This species, growing with *Aspidium Thelypteris*, forms a tough woody network over a considerable part of this bog.

Menyanthes trifoliata.—The rhizome of this plant assumes an approximately horizontal position from 3 to 9 cm. deep, while the roots may either be horizontal or vertical. The roots were found as much as 12 cm. deep. They were few in number and comparatively short but much branched.

Eupatorium perfoliatum.—The base of the stem of this species assumes an approximately horizontal position near the soil surface

FIG. 6.—*Lathyrus palustris*, map of rhizome system: *L*, living attachment; *A*, aerial stems; *D*, dead rhizome tips; solid black lines, living rhizomes; depth 6 cm.

and the roots grow almost horizontally from this. In the bog the roots were found to reach a depth of 4–6 cm., while in mineral soil where the water table was much lower they reached down to depths of 5–10 cm.

It should be noted that a very high percentage of all the living plant tissue in the bogs studied is above the water level. The part above water usually consists of a mat about 6 cm. thick, made of a coarse feltlike tangle of living roots and rhizomes largely of *Aspidium*, *Carex*, *Vaccinium*, and *Menyanthes*, and often a dense growth of *Sphagnum*. It is difficult to penetrate this tough mat, while just below the water level a sharp contrast appears. Here a fibrous, light brown peat is found in which the dead parts of these same species can often be recognized to considerable depths. Almost the only living parts encountered are occasional roots or rhizomes of *Typha*, *Sagittaria*, *Scirpus*, or *Eriophorum*.

MARKLE (6) working in New Mexico, and WEAVER (9, 10) in the prairies, have noted that two dominant species in an association are not likely to have their roots so placed as to have any marked subterranean competition. This is obviously not the case in the main parts of this bog flora, where two codominants, *Vaccinium macrocarpon* and *Aspidium Thelypteris*, have practically the same level, and together dominate the greater area of the bog. Neither of these two dominant species seems to be overcoming the other. Mingled with these are a number of less important species also at the same level. On the other hand, the deep-rooted forms in which there is no competition are in no case crowding out the shallow rooted species.

Aerenchyma is very common both above and below the water table. Roots and rhizomes which grow below water are all very rich in air tissue, with the exceptions of *Betula pumila* and *Salix* spp. In these species no aerenchyma was found in any of their parts, nor, with the exception of *Decodon verticillatus*, was it found in any woody perennial examined. In most cases herbaceous species have a great deal of aerenchyma.

Tests for H ion concentration in the soils were made by means of the colorometric indicators made by the La Motte Chemical Products Company. The records were made in terms of specific reaction (11). The tests were made in the white porcelain "spot plates," such as are commonly used in the chemical laboratory. By means of pipettes the water to be tested was drawn off from the absorbing parts of the roots. In all cases fruiting or flowering plants were used. Both pipettes and spot plate were thoroughly rinsed in the water to be tested before beginning each test. A series of samples was taken across the bog from the lakeward margin toward the landward side. The water of the lake was uniformly 30 alkaline. The reaction on the floating mat gradually changed from alkaline to neutral, and finally reached 10 acid, 2 or 3 m. from the lakeward margin. This reaction was uniform across the entire mat until the decaying peat was reached on the landward side. Here the acidity decreased until it reached neutrality at a point where the mat was so decomposed that it would no longer bear the weight. It was not possible in any case to discover a difference in

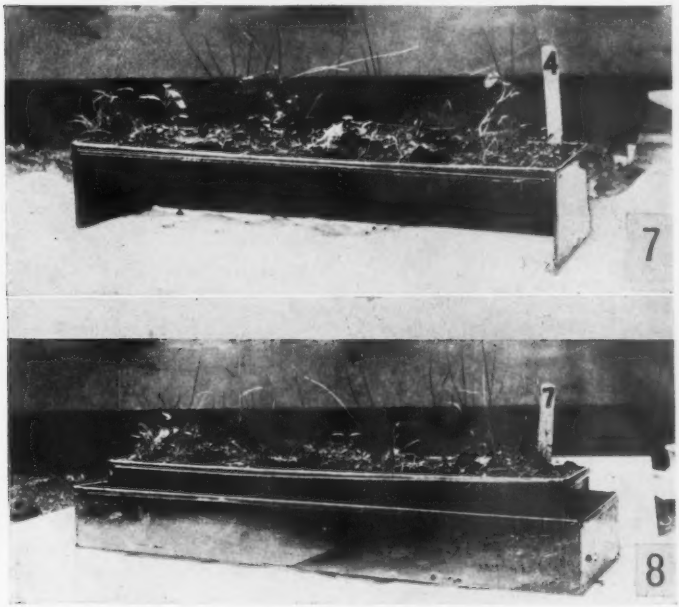
reaction in the water drawn from the immediate surface of the roots and that taken from the peat near by. Hence it seems that all roots in a given area are subject to approximately the same soil reaction. Members of a given species, however, often showed considerable latitude in tolerance to soil reaction. The widest variation found was that of *Larix laricina*. At Mineral Spring, Indiana, in a very old bog in which the peat has become considerably decayed, the reaction about its rootlets was 10 alkaline; at Hillside, Indiana, in a mature bog of fibrous peat, 300–1000 acid; and in the comparatively young mat at Cedar Lake, 10 acid. No marked differences could be seen in subterranean systems of members of the same species growing in peat and mineral soils, or in various natural concentrations of H and OH ions.

Other species which showed a narrower range of tolerance to reaction follow, with the extremes of reaction found in each. Water squeezed from *Sphagnum* had a specific acidity of 100 to 1000; *Aspidium Thelypteris*, *Scirpus validus*, and *Betula pumila* all varied from 10 alkaline to 10 acid; *Sarracenia purpurea*, *Drosera rotundifolia*, and *Vaccinium macrocarpon* varied from neutral to 300 acid. The peat about the roots of *Decodon verticillatus* at the margin of the mat was approximately neutral, while the lake water into which this species was migrating was 30 alkaline.

Experimentation

In order to determine the factors involved in the horizontal placing of roots in bogs, the following experiment was carried out. Galvanized iron boxes, 10 cm. × 15 cm. × 55 cm., were made with the bottom and one side replaced by a diagonal pane of glass. This glass was covered on the outside by a piece of galvanized iron which could readily be removed, making it easy to make observations of the roots, but at the same time keeping them protected from the light except during examination. In certain parts of this experiment, as indicated later, a fixed water table was maintained by keeping the boxes in pans of water of proper depth (figs. 7, 8). All metal surfaces were given two coats of Acme asphalt varnish. Various germinating seeds were planted in these boxes. The most

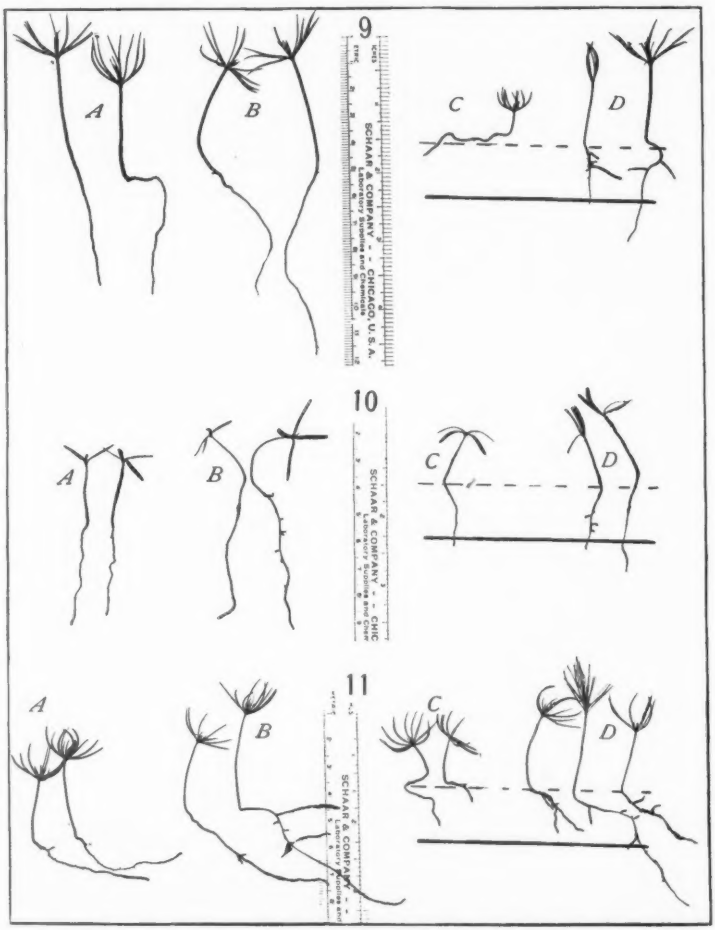
significant results are shown in figs. 9–11. Distilled water was used throughout the experiment for watering the seedlings and maintaining the water level. This distilled water had a reaction of approximately 1 (neutral), although in some cases it showed a slight trace of acidity from carbonic acid. All the peat maintained



FIGS. 7, 8.—Growing boxes used in experimental work: fig. 7, growing box with diagonal glass side facing camera (removable sheet iron false side is in place covering glass); fig. 8, growing box similar to that in fig. 7 placed in pan containing water, thus maintaining fixed water level in growing box.

a specific acidity of 3 throughout the experiment. The garden soils varied from specific reaction 1 to specific alkalinity 10. This last reaction was reached near the end of the experiment in the wet garden soil. The experiment was carried on for about two months during February, March, and April, 1921, in the cool room of the greenhouse. At the end of this period the plants were removed

from the soil and characteristic specimens, showing as far as possible the extremes of size and form, were photographed.



FIGS. 9–11.—*A*, seedlings grown in moist garden soil; *B*, in moist brown fibrous peat; *C*, in garden soil in which water level was maintained at approximately 2 cm. below soil surface; *D*, in brown fibrous peat in which water level was kept at about 2 cm. below soil surface; broken line shows location of soil surface, solid line of water surface; fig. 9, *Pinus Strobus;* fig. 10, *Abies balsamea;* fig. 11, *Picea excelsa.*

1. *Pinus Strobus* (fig. 9 *A*, *B*).—In both moist garden soil and moist peat the tap root assumed approximately the vertical position,

deviation from this direction being chiefly from the interference of the diagonal glass side of the growing box. It is also noteworthy that in both of these cases laterals were lacking. In garden soil in which a water table was kept, capillarity caused the water to rise until the soil was practically saturated to the surface. Only one pine seedling lived throughout this part of the experiment. A number of seedlings started to grow, however, and all behaved in the same way. All the tap roots showed a slight tendency to penetrate the soil, but the plants soon fell over and the roots grew in an approximately horizontal direction, producing no laterals (fig. 9 *C*). Those growing in peat in which a water level was kept behaved in a still different manner. On account of the fibrous spongy structure of the peat, aeration was possible to the water surface. The tap roots grew downward about as in the moist garden soil and peat, although somewhat less rapidly. The most obvious difference began to appear when the tips of the tap roots reached the water level, when growth almost completely ceased. In a few cases the roots continued to grow slowly for some time after reaching the water level, but in all cases these longer roots died back to about the surface of the water. Strong laterals always appeared and took approximately the horizontal position. The study of this species was suggested by the statement made by PULLING (7) that *Pinus Strobus* has "a deep rigid root habit." In examining the root systems of this tree at various ages in the Hillside bog and at Mineral Spring no root was found extending more than a few centimeters deep and all were horizontal. From this experiment and from field observation it is obvious that the tap root is ephemeral under bog conditions, and that very shallow horizontal laterals make up the entire root system.

2. *Abies balsamea* (fig. 10).—Under all the conditions of this experiment the roots grew downward and all were putting out laterals at the end of the experiment. At the water surface the roots behaved as in the case of *Pinus Strobus*.

3. *Picea excelsa* (fig. 11).—Throughout there was evident a decided tendency for the roots to assume an almost horizontal position. In some cases the roots penetrated somewhat below the water surface without showing any ill effects, although the rate of growth was greatly checked on entering the water.

Discussion

A comparison of the action of the roots of seedlings under experimental control with observations in the field shows that there are four general types of behavior of subterranean organs in these bogs.

1. The roots and rhizomes assume an approximately horizontal position above the water table. Typical forms are *Aspidium Thelypteris*, *Picea excelsa*, *Larix laricina* (fig. 2), *Carex filiformis*, *Pogonia ophioglossoides*, *Potentilla palustris*, *Lathyrus palustris*, and *Vaccinium macrocarpon*.

2. The tap roots of the seedlings die at the water surface and horizontal laterals appear above. Examples are *Pinus Strobus* and *Abies balsamea*.

3. All underground parts are approximately vertical and die near the water surface, usually with non-horizontal laterals or adventitious roots appearing above, as in *Sphagnum*, *Calopogon pulchellus*, *Sarracenia purpurea* (fig. 5), and *Drosera rotundifolia*.

4. The rhizomes and roots are able to grow under water. Important species are *Typha latifolia*, *Sagittaria latifolia*, *Scirpus validus*, *Eriophorum*, *Betula pumila*, and *Decodon verticillatus*.

While doubtless there are many factors influencing the location of roots and rhizomes in bog soils, it becomes evident that the two most potent are hereditary tendencies and water level. Rhizomes of certain plants, such as *Typha*, assume a depth apparently determined by heredity, which places them below the surface of the water. Such plants as can readily endure submergence are able to persist in the bog unless other factors interfere. Obligate deep-rooted plants which are intolerant of submergence are eliminated by water from this flora. Rhizomes of certain other species, as for example *Aspidium Thelypteris*, are in all cases superficial, thus permitting their development above water. On the other hand, the roots especially seem to respond rather readily to the water surface. A number of species have only shallow roots where the water table is high, but deeper ones in most peat or moist mineral soil. This was found to be especially well illustrated by *Aspidium Thelypteris*, *Pinus Strobus*, and *Acer rubrum;* hence it is apparently not the quality of the soil but the presence of water

that induces shallowness. Doubtless the lack of oxygen plays a considerable part in checking growth under water. It is possible that bog toxins may in part be responsible for the poor development or in some cases even the death of the roots of certain species.

Summary

1. Subterranean systems of plants growing on floating mats were found to be very superficial, nearly all the living tissue being above the level of the water.

2. No evidence was found to suggest that acidity or toxins are involved in the shallowness of these organs. Water level was apparently the important factor, aside from hereditary tendencies in certain species.

3. Roots of codominants were in close competition without apparent damage resulting to them.

4. Three types of behavior were noted, resulting in the superficial placing of the living parts of bog plants: (*a*) the parts assume the horizontal position above the water level; (*b*) the tap root is ephemeral in the bog and is replaced by horizontal laterals; (*c*) the roots are all vertical and die at the water surface.

5. Certain plant parts were found to be able to thrive under the water in the bogs.

6. There is no apparent marked difference in the subterranean organs of a given species growing in a bog and in comparable conditions in mineral soils.

I wish to express my appreciation to Dr. H. C. COWLES and Dr. GEO. D. FULLER for encouragement and helpful suggestions during the progress of this work.

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LITERATURE CITED

1. CANNON, W. A., The root habits of desert plants. Carn. Inst. Wash. Publ. 131. 1911.
2. ———, Notes on root variation in some desert plants. Plant World **16**: 323–341. 1913.
3. HAYDEN, ADA, The ecological subterranean anatomy of some plants of a prairie province in central Iowa. Jour. Bot. **6**:87–105. 1919.

4. HITCHCOCK, A. S., Studies on subterranean organs. Trans. Acad. Sci. St. Louis **9**:1–8. 1899; **10**:131–142. 1900.
5. HOPKINS, C. G., et al., Lake County soils. Univ. Ill. Agric. Exper. Sta. Soil Rept. no. 9. 1915.
6. MARKLE, M. S., Root systems of certain desert plants. BOT. GAZ. **64**:177–205. 1917.
7. PULLING, H. E., Root habits and plant distribution in the far north. Plant World **21**:223–233. 1918.
8. SHERFF, E. E., The vegetation of Skokie Marsh. BOT. GAZ. **52**:415–435. 1912.
9. WEAVER, J. E., The ecological relations of roots. Carn. Inst. Wash. Publ. 286. 1919.
10. ———, Root development in the grass land formation. Carn. Inst. Wash. Publ. 292. 1920.
11. WHERRY, E. T., Soil acidity and a field method for its measurement. Ecology **1**:160–173. 1920.
12. YAPP, R. H., Wicken Fen. New Phytol. **7**:61–81. 1908.

MORPHOLOGICAL STUDY OF CARYA ALBA AND JUGLANS NIGRA

THEO. HOLM

(WITH PLATES XV, XVI, AND ONE FIGURE)

The systematic position of the Juglandaceae has been somewhat disputed, some workers having referred the family to the close vicinity of the Anacardiaceae, although the floral structure is very different, and the resiniferous ducts so characteristic of these are totally absent from the Juglandaceae. Since the floral structure has been incorrectly explained in American manuals, it is thought advisable to redescribe this. Moreover, there are several points with regard to the internal structure and the germination which may be of interest to the student of plant morphology, besides that the American representatives are very little known from this particular point of view.

Flower

According to EICHLER,[1] the staminate flower of *Carya* (fig. 1) consists of two prophylla (*P*), which grow together with the subtending bract (*L*), thus forming a three-lobed involucre (figs. 2, 3) suggesting that of *Carpinus;* there is no perianth. The stamens, two to ten, have very short filaments, and are free (fig. 4). In the pistillate flower (figs. 5, 6) the bract is much longer than the two prophylla and the single, or very seldom two perianth-leaves (figs. 7, 8). In other words, the staminate flower has a three-lobed involucre, but no perianth; on the other hand, the pistillate has a very rudimentary perianth, consisting of a single leaf, or very seldom of two minute leaves.

This simple and natural explanation of the floral structure, however, has been ignored or completely misunderstood by subsequent writers in this country. It is strange to see the incorrect description that has been given in the treatments of the North

[1] EICHLER, A. W., Blüthendiagramme. 2:32. 1875.

American flora. For instance, in GRAY'S *New manual of botany*[2] the staminate flower of the Juglandaceae is said to have "an irregular calyx adnate to the bract," and the pistillate flower to have "a regular 3–5-lobed calyx adherent to the ovary." Furthermore, under *Carya* the staminate flower is simply described as "stamens 3–10; filaments short or none, free," while "a four-toothed calyx; petals none" is attributed to the pistillate flower.

SARGENT[3] describes the staminate flower of *Carya* as follows: "Calyx usually 2-, rarely 3-lobed, subtended by an ovate acute elongated bract free nearly to the base, and usually longer than the ovate rounded calyx-lobes." In the pistillate flower the calyx is said to be "reduced to a single posterior lobe," and the ovary to be "inclosed in a perianth-like slightly 4-ridged involucre, composed by the more or less complete union of an anterior bract and 2 lateral bractlets, adnate below to the ovary, unequally 4-lobed at the apex."

BRITTON[4] describes the staminate flower of Juglandales as "consisting of 3–numerous stamens with or without an irregularly lobed perianth adnate to the bractlet," and the pistillate "bracted and usually 2-bracteolate with a 3–5-lobed (normally 4-lobed) calyx or with both calyx and petals." Under *Hicoria* the staminate flower is said to possess "a calyx adnate to the bract, 2–3-lobed or 2–3-cleft," and the pistillate flower is described as "bract fugacious or none; calyx 4-toothed; petals none." This same description is reprinted in the second edition of BRITTON and BROWN'S *Illustrated flora*.

By SMALL[5] the staminate flower of the Juglandales is said to possess "a 2–6-lobed calyx bearing several rows of stamens, or the calyx obsolete," while the pistillate flower is described as "consisting of an involucrate incompletely 2–4-celled gynaecium: calyx partially adnate to the gynaecium." Under *Hicoria* the staminate

[2] ROBINSON and FERNALD, A handbook of the flowering plants and ferns of the central and northeastern United States and adjacent Canada. p. 330. 1908.

[3] SARGENT, C. S., The Silva of North America. **7**: 1895.

[4] BRITTON, N. L., Manual of the flora of the Northern States and Canada. 3d. ed. p. 322. 1907.

[5] SMALL, J. K., Flora of the southeastern United States. 2d. ed. p. 332. 1913.

flower is described as "a 3-lobed calyx," and the pistillate as "a calyx of 1 sepal adnate on the ovary."

With respect to the flowers of *Juglans*, EICHLER describes the staminate flower (fig. 10) as consisting of two prophylla (*P*), which with the two to five perianth leaves grow together with the subtending bract; the six to forty stamens have very short, free filaments. The pistillate flower has a superior, four-leaved perianth; the ovary, bract, and prophylla all unite together, their edge being visible as an indented line below the perianth (fig. 13). The staminate flower, therefore, has two prophylla and a two to four-leaved perianth, which grow together with the subtending bract; the pistillate has a superior perianth of four leaves, and the subtending bract beside the two prophylla grow together with the ovary.

As was the case of *Carya*, this very simple structure has been completely misunderstood by subsequent writers in this country. ROBINSON and FERNALD do not describe the staminate flower of *Juglans* in any other way than "stamens 12–40; filaments free, very short." On the other hand, the pistillate flower is said to possess "a four-toothed calyx, bearing four small petals at the sinuses."

SARGENT attributes "a perianth sessile or pedicellate, three to six-lobed in the axil of an adnate to an ovate acute bract free only at the apex" to the staminate flowers. The pistillate flower is described as being invested by a villous involucre adnate to the ovary, and formed by the union of the anterior bract, sometimes free nearly to the base, and two lateral bractlets free only at the apex, and variously cut into a laciniate border shorter than the erect lanceolate calyx lobes inserted at the summit of the ovary.

By BRITTON the staminate flower of *Juglans* is said to have a "perianth 3–6-lobed," and the pistillate "calyx 4-lobed, with 4 small petals adnate to the ovary at the sinuses." SMALL describes the staminate flower in the same manner, while the pistillate is said to have "the sepals adnate to the ovary."

In "*Flora of the District of Columbia and vicinity*," published under the auspices of the Smithsonian Institution (1919), no

description is given of the floral structure, except that the fruit is "a nut inclosed in a shuck or husk, the meat or embryo 4-lobed."

Carya alba

Root

The primary structure may be studied from the thin lateral roots of the seedling. No secondary increase takes place during the first season; thus the epidermis and cortical parenchyma remain intact. The latter consists of about ten compact strata, and the endodermis is very thick-walled, representing a U-endodermis. A thin-walled pericambium of a single layer surrounds the pentarch stele, in which thick-walled conjunctive tissue is much in evidence, surrounding the vessels, and as a narrow group in the center of the stele. On the other hand, increase in thickness is readily noticeable in the primary root of the seedling in its second year. In this the epidermis and the primary cortex have become thrown off, replaced by many layers of homogeneous, thin-walled cork of pericambial origin. Inside the cork is a narrow zone of thin-walled parenchyma, which surrounds a circular band of small strands of stereome (fig. 9, *St*), supporting the leptome (*L*) of the secondary mestome strands. There is now a continuous ring of cambium, from which the secondary mestome is developed, and the thickness of the root depends largely upon the presence of a very broad, central, thin-walled parenchyma, a true pith, containing starch in abundance, but no crystals.

The development of stereome in the root deserves attention, since, so far as known, this tissue does not appear to be commonly represented in roots. In *Carya* it is a secondary structure, which seems to be the general case wherever it occurs in roots. As a primary structure the stereome is extremely rare, known only in a very few genera, *Dirca*, *Anona*, *Celtis*, etc., where it is developed in the primary leptome.

Stem

The apical internode of the seedling is densely covered with hairs of different types, unicellular, long, pointed, which are either single or developed in tufts; and large, sessile, pluricellular, glandular of peltate shape. The cuticle is smooth and the epidermis

is quite thick-walled. The cortex is differentiated into a peripheral sheath of collenchyma, three or four strata, and an interior of thin-walled parenchyma, five to six layers. Rhombic crystals of calcium oxalate were observed in the collenchyma, while aggregated crystals occurred sparingly in the inner part of the cortex. The phellogen arises in the hypodermal stratum of the collenchyma. A thin-walled, starch-bearing endodermis surrounds a band of small isolated strands of stereome, separated from each other by narrow rays of parenchyma. The stele shows a continuous zone of leptome, cambium, and hadrome in deep rays, accompanied by many layers of libriform. A homogeneous, slightly thick-walled pith, destitute of starch, occupies the central portion of the stele; the pith is not septate.

In branches of the mature tree the cork appears in many thin-walled strata; the stereome is well represented as several, until seven, concentric bands of isolated strands, the result of one season's growth. Large rhombic crystals abound in the leptome, and the hadrome is divided by broad tangential bands of moderately thickened libriform. The very thick-walled, porous vessels so characteristic of *Juglans* do not occur in *Carya*, and the pith is nowhere septate.

Leaf

Viewed in superficial sections the ventral epidermis shows the lateral cell walls prominently undulate, hairs and stomata being absent. In the dorsal epidermis the lateral walls are less undulate, but stomata and hairs are abundant; of these the former are all of the same size, and surrounded by four to seven ordinary epidermis cells; the hairs are of the same types as observed upon the stem.

Viewed in transverse sections the cuticle is thick and smooth on both faces of the leaf blade, and the outer cell wall of epidermis is thickened. Large oil drops abound in the ventral epidermis. The mesophyll consists of a typical palisade tissue of one stratum, covering a very open pneumatic tissue of three to five layers. Numerous large cells containing aggregated crystals are scattered in the palisade tissue, while single rhombic crystals abound in the pneumatic tissue, especially close to the veins.

The midrib of the leaflet has a very thick-walled epidermis, and a few hypodermal strata of collenchyma on both faces, bordering on a water-storage tissue with many aggregated crystals. There is no endodermis, but a closed sheath of stereome, which surrounds a stele of several collateral mestome strands, all of which turn the leptome toward the periphery, and with the hadrome bordering on a central pith. The pith is thin-walled, and contains some few crystals, aggregated as well as single, rhombic. The much thinner lateral veins are more or less imbedded in the mesophyll, and contain only one mestome strand, surrounded by a chlorophyll-bearing parenchyma sheath. The structure of the rhachis and the petiole is identical with that of the midrib, thus containing a typical stele of several mestome strands, a sheath of stereome, and a cortex of which the peripheral strata are collenchymatic.

Juglans nigra

SEEDLING

In the Juglandaceae the cotyledons are hypogeic in all the species examined, with the exception of *Pterocarya caucasica* C. A. Mey., which germinates with the cotyledons above ground. It is a marked characteristic of the Dicotyledons that the cotyledons are epigeic, and it is only in a relatively few families that they remain underground, serving only as storage organs. Subterranean cotyledons, however, are known from trees, shrubs, and herbs, terrestrial as well as aquatic, but the Nymphaeaceae is the only family in which all the species, so far as known, germinate with the cotyledons underground and inclosed within the seed. In the other families subterranean cotyledons are characteristic of some certain groups, for instance, Vicieae, or genera: *Phryma*, *Sanguinaria*, *Caulophyllum*, *Panax*, *Melittis*, *Collinsonia*, *Quercus*, *Castanea*, *Aesculus*, *Sassafras*, *Citrus*, *Aegle*, *Mangifera*, *Persea*, *Prunus*, etc. While in some genera the majority of the species germinate with epigeic cotyledons, some exceptions occur, for instance in *Anemone*, *Oxalis*, *Clematis*, *Aristolochia*, *Phaseolus*, *Rhamnus*, etc., where some few species have the cotyledons constantly subterranean.

Characteristic of the seedlings with hypogeic cotyledons is the generally strong development of the primary root. In the Nymphaeaceae, *Nuphar*, *Nymphaea*, and *Victoria*, however, the primary

root increases but little in length during the first stages of germination, its function becoming performed by a whorl of very long root hairs developing from the base of the root as soon as the seed germinates. In *Nelumbium*, on the other hand, the root remains rudimentary, and no whorl of hairs becomes formed.[6]

The structure of the seedling of *Juglans nigra* (text fig. 1) agrees with that of *J. regia* L. as described by SCHACHT[7] and KLEBS.[8] The primary root (*R*) is stout and quite long, but it is not fusiform as in *Carya*. There is no hypocotyl, and the cotyledons remain underground, inclosed, or partly so, by the bony endocarp. They are short petioled, auriculate at base, two-lobed, and the lobes bifid. The petioles form a sheath (*S*) around the plumule, which during the first season develops into a glabrous short shoot. The first four or five leaves are very small, scalelike, and entire; the

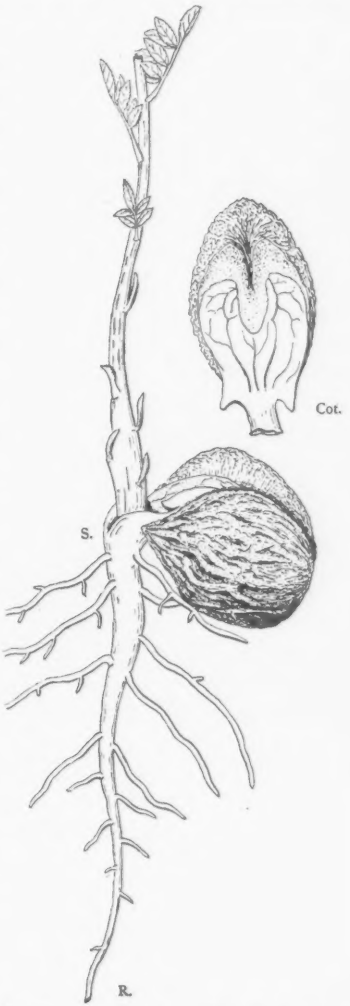


FIG. 1.—Young seedling of *J. nigra*, showing primary root (*R*), sheath formed by cotyledons (*S*), and aerial shoot; two-thirds natural size.

[6] POITEAU, Mémoire sur l'embryon des Graminées, des Cypéracées, et du *Nelumbo*. Ann. Mus. Hist. Nat. 13:397. 1809.

MIRBEL, B., Observations anatomiques et physiologiques sur le *Nelumbo nucifera*. *Ibid.* p. 474.

[7] SCHACHT, H., Beiträge zur Anatomie und Physiologie der Gewächse. p. 105. 1854.

[8] KLEBS, G., Beiträge zur Morphologie und Biologie der Keimung. Untersuch. Bot. Inst. Tübingen 1:556. 1881–1885.

succeeding are small, odd-pinnate, with three to seven leaflets. Buds are present in the axils of all the leaves, including the cotyledons; and in specimens which were injured at the apex, several of these buds had grown out into erect shoots (fig. 1).

In *Carya alba* and *C. glabra* (Mill.) Spach the seedlings agree with those of *Juglans*, but the root is fusiform. Moreover, the first two or three leaves succeeding the scalelike are unifoliate to trifoliolate, with the terminal leaflet very large, roundish, and far surpassing the lateral in size.

Root

The primary root of the seedling is stout and fleshy at the base, owing to the large development of the parenchymatic tissues, primary as well as secondary. The successive development of the various tissues may readily be seen in the same root, when examined from base to apex. In beginning with the basal swollen portion, the structure is as follows. Only some few, more or less broken strata of the primary cortex and part of the endodermis still adhere to the root, which is now covered by four or five layers of thin-walled cork of pericambial origin. Inside the cork is a broad parenchyma, the secondary cortex, rich in starch, and interrupted by two concentric bands of isolated strands of stereome. The stele shows an almost continuous zone of leptome and cambium, while the hadrome corresponds with eight distinct mestome strands. On the inner flank of the interfascicular cambium some few young vessels are visible; moreover, there are four rays of narrow protohadrome vessels readily distinguishable from the secondary by their narrow lumen. The central portion of the stele is occupied by a broad starch-bearing pith. In comparing this structure with that of the younger apical part of the same root, the following distinctions are noticeable. There is a glabrous epidermis, destitute of root hairs, and the primary cortex is a broad parenchyma without starch or crystals. Inside the endodermis is a pericambium of a single layer, in which tangential divisions have commenced, indicating the beginning formation of the cork (fig. 15, *Co*). Bordering on the pericambium is a zone of about eight layers of thin-walled parenchyma (fig. 15, C^+), representing a secondary cortex.

This tissue does not contain starch or crystals, but is interrupted, here and there, by narrow strands of secondary leptome, covered by young thin-walled stereome (fig. 16, *St*), in two concentric bands. Then follows a continuous zone of cambium connecting the four collateral mestome strands, and from which (the cambium) some few young, wide, porous vessels have become developed. Beside this secondary mestome the protohadrome vessels are very distinct, forming four short narrow rays of annular and spiral vessels.

The very commencement of the formation of these secondary tissues, the cortex and the collateral mestome strands, but not the cork, can only be traced at the youngest, the apical, portion of this root. The earliest appearance of the secondary formations depends upon a double meristem arising along the inner flank of the primary leptome, and from which secondary leptome and hadrome become formed. Outside the protohadrome the pericambium then commences to divide, forming another meristem, which in *Juglans* gives rise first to parenchyma, a secondary cortex, and a little later to a peripheral cork. Regarding the stereome, so amply represented in the secondary cortex, this tissue is totally absent from the primary structure of this root. It arises outside the leptome (fig. 16, *St*), and is formed by the secondary cortex, soon developing to distinct separate strands, arranged in one or several more or less concentric bands.

In old, thick, lateral roots the epidermis and the primary cortex are replaced by many layers of thin-walled, homogeneous cork, which surround a broad zone of compact thin-walled parenchyma (secondary cortex), the cells of which contain much starch and numerous aggregated crystals of calcium oxalate. In this secondary cortex are five or six concentric bands of isolated stereome strands (fig. 17, *St*). Viewed in longitudinal sections these stereome strands traverse the parenchyma in wavy, not parallel lines. The stele contains a peripheral zone of almost continuous leptome, also several strata of cambium, beside a dense mass of hadrome, in which wide porous tracheids with bordered pits are quite conspicuous. Thick-walled libriform, and thin-walled parenchyma with starch represent also a large part of the stele. The medullary

rays (fig. 17, *PR*) are narrow, mostly of a single row of cells, compressed radially, and filled with starch. The protohadrome vessels are readily seen in the center of the root, surrounded by strata of thick-walled conjunctive tissue; no pith is developed.

STEM

The young shoot, examined in the early spring, is densely covered with hairs, especially glandular. Unicellular, pointed hairs are also common, and these occur in clusters of from two to fifteen, or even more. The cuticle is thick, smooth, and the epidermis is thick-walled. During the fall the epidermis is replaced by a hypodermal cork of heterogeneous structure, thin-walled strata alternating with thick-walled. This cork is developed from the hypodermal stratum of a collenchyma. Inside the collenchyma is a broad, compact, thin-walled parenchyma, filled with starch and large aggregated crystals. Two concentric bands of stereome are developed in the inner part of the cortex. There is no endodermis, and the stele shows a continuous zone of leptome, interspersed with cells containing single rhombic crystals. The cambium is well represented, and in the hadrome the porous vessels are remarkably thick-walled. Cells containing single crystals occur also in the hadrome. The medullary rays are narrow, mostly of a single row of cells, containing starch. There is a relatively thick-walled pith, porous, filled with starch and aggregated crystals, and becoming soon septate as in *Juglans regia* and *Pterocarya*, as mentioned by SOLEREDER. A corresponding structure is exhibited by the old thick branches, but in these the stereome occurs in a larger number of concentric bands, twelve or even more. The pith also is here divided by transverse septa.

Finally may be mentioned that the internodes of the young seedling are perfectly glabrous, and a cork is developed from the hypodermal layer of the cortex, or from the stratum inside this; both cases may be observed in the same section. There is no collenchyma in these internodes during the first season, and the cortex is thin-walled throughout, destitute of starch and crystals. Inside the barely distinguishable endodermis are four or five layers of thick-walled stereome, forming arches, more or less continuous

as a closed sheath. Bordering on the stereome is a broad zone of thin-walled parenchyma, with narrow isolated strands of leptome. The cambium forms a closed ring, and the hadrome is in deep rays with much thick-walled libriform. The pith is homogeneous, thin-walled, filled with starch, but solid, not septate as in the shoots of the mature tree.

Leaf

When unfolding, the leaves are very hairy, especially on the dorsal face, and the hairs are of the types that occur on the young shoots. The stomata are confined to the dorsal face, and lack subsidiary cells. They represent two sizes, both of which are equally common. Viewed in superficial sections the lateral walls of epidermis are straight on both faces of the leaf blade. With regard to the distribution of the various hairs, the pointed, fasciculate, abound beneath the veins, and are absent from the ventral face; the glandular are common on both faces; but the largest type, sessile with a large head, are confined to above and below the mesophyll. The mesophyll consists of a compact palisade tissue of a single stratum, or sometimes two strata (fig. 18, *P*), covering a very open pneumatic tissue with numerous large cells containing aggregated crystals, especially close to the epidermis.

The midrib is supported by several hypodermal layers of collenchyma on both faces, and is furthermore surrounded by a water-storage tissue. There is no endodermis, but a closed sheath of thick-walled stereome in several strata surrounding the steloid midvein, which is composed of an obtusely triangular band (in cross-sections) of collateral mestome strands inclosing a central parenchyma, a pith. In these mestome strands the hadrome faces the pith, while the leptome turns toward the periphery, even in the ventral part of the stele. Characteristic of the hadrome is the abundance of thin-walled parenchyma in continuation with the vessels. The lateral veins contain only single mestome strands which are supported by stereome extending to the ventral and dorsal epidermis, broken on the sides by thin-walled cells of a parenchyma sheath.

Between the leaflets the rhachilla is hemicylindric (in cross-sections), very hairy, with long stalked glandular hairs. Several

hypodermal and continuous layers of collenchyma surround a broad thin-walled cortex, rich in chlorophyll, and with some aggregated crystals. No endodermis is developed, but a closed sheath of stereome surrounds a stele of collateral mestome strands as in the midrib of the blade. The pith is solid, not divided into septa.

Examined just below the basal pair of leaflets, the petiole is hairy like the rhachilla, and shows the same structure, except that there are two thin collateral mestome strands located in the cortex, thus outside the stele, and in these the leptome is covered by a few layers of stereome; the pith is solid.

COTYLEDONS

Although completely subterranean, the epidermis of the cotyledons shows stomata, but relatively only a few, on both faces of the thick fleshy blade. The lateral cell walls are straight on both faces, and the lumen is about the same, or slightly wider on the ventral face. The mesophyll lacks palisade cells, and is composed of a large, thin-walled, compact parenchyma of roundish cells. All the mestome strands are single, collateral, surrounded by parenchyma sheaths, and are imbedded in the mesophyll. The leptome is generally much better represented than the hadrome, and no mechanical tissues are developed in these leaves.

Juglans cinerea shows the same structure as *J. nigra*, with the only exception that the pericycle in the stem represents an almost closed sheath interspersed with large, thick-walled, and porous sclereids. The pith is discoid, and the diaphragms contain many aggregated crystals. The pointed hairs of the leaf are more abundant than in *J. nigra*, and occur mostly in clusters of two to eight on the dorsal face of the blade.

Characteristic of *Juglans* and *Carya* is thus the ample representation of mechanical tissues, as collenchyma, stereome, and libriform. Of these the collenchyma occurs in the stem, the periphery of the cortex proper, and in the leaves as hypodermal strata on both faces of the midrib. The stereome occurs as a secondary tissue in the cortex of the root and stem, as well as pericyclic arches or, sometimes, forming a closed sheath, interspersed with sclereids

in *J. cinerea;* it occurs also in the leaves forming a sheath around the midrib. Thick-walled libriform is noticeable already in the apical internodes of the seedling, and in branches of the mature tree the hadrome is divided by broad tangential bands of this tissue. In old roots of *Juglans* the libriform is much in evidence.

With respect to the distribution of the calcium-oxalate as single or aggregated crystals, SOLEREDER (Anatomie Dicot.) calls attention to the very varied occurrence of these types of crystals. In *Juglans nigra* aggregated crystals were observed in the inner part of the cortex and pith of the stem, as well as in the pneumatic tissue of the leaf. On the other hand, single crystals were noticed in the leptome and hadrome of the stem. In *Carya alba* aggregated crystals were observed in the cortex and leptome of the stem, as well as in the palisade tissue of the leaf, and in the pith of the steloid midrib. Single crystals, on the other hand, were found in the collenchyma of the stem, as well as in the pneumatic tissue of the leaf and in the pith of the steloid midrib; thus both types of crystals occur in the pith of the midrib.

Of greater interest, however, is the singular structure of the pith in *Juglans* and *Pterocarya*. The history of this structure, the discoid pith, dates back to GREW,[9] who discovered it in *Juglans*. By MIRBEL[10] it was mentioned as peculiar to *Phytolacca*, *Nyssa*, and *Juglans*. DE CANDOLLE[11] found a discoid pith in *Jasminum officinale*. MORREN,[12] in describing discoid piths of plants, enumerates several other plants, for instance, *Begonia argyrostigma*, while this writer found the pith to be solid in *B. undulata*, *B. semperflorens*, and *B. papillosa*. According to SOLEREDER the discoid pith is characteristic of two herbs, *Diplotaxis* and *Pedalium*, and among woody plants he enumerates *Wormia* (Dilleniaceae), *Fouquiera* (Tamariscineae), *Prinsepia* (Chrysobalanaceae), *Aucuba*, *Halesia*, *Paulownia*, *Daphniphyllum* (Daphniphyllaceae), as well as the

[9] GREW, N., Anatome plantarum. *pl. 19. fig. 4.* 1682.

[10] MIRBEL, B., Elémens de Physiologie végétale et de Botanique. 1:112. 1815.

[11] DE CANDOLLE, A. P., Organographie. 1:167. 1827.

[12] MORREN, C., On the discoid piths of plants. Ann. Nat. Hist. London. 4:73. 1839–1840.

genera mentioned in the preceding. By FOXWORTHY[13] a general discussion of discoid pith has been presented. Finally by the writer[14] the structure of the pith in *Phytolacca decandra* L. has been described and figured.

While the discoid pith is thus characteristic of the species of certain genera, it has been shown that in *Begonia*, *Forsythia*, *Jasminum*, and *Phytolacca* this structure occurs only in certain species. *Juglans* and *Pterocarya* are definitely separated from the other genera by the possession of a discoid pith. It is a very interesting structure, which, however, must not be confounded with cases where the pith is solid, and divided by horizontal diaphragms of sclerotic cells, so characteristic of many Magnoliaceae, Anonaceae, Ternstroemiaceae, and Convolvulaceae.

CLINTON, MD.

EXPLANATION OF PLATES XV, XVI

PLATE XV

Carya alba

Figs. 2, 3, 4, 7, 8, 10, 11, 13, and 14 are enlarged.

FIG. 1.—Staminate flower: *St*, stem; *L*, bract; *P*, prophylla; *S*, stamens.

FIG. 2.—Involucre of staminate flower, seen from outside.

FIG. 3.—Staminate flower, side view.

FIG. 4.—Stamen.

FIG. 5.—Pistillate flower: *PL*, perianth leaves; other letters as preceding.

FIG. 6.—Pistillate flower with single perianth leaf.

FIG. 7.—Pistillate flower, side view; *PS*, petiole.

FIG. 8.—Pistillate flower, seen from above.

FIG. 9.—Cross-section of inner part of primary root of seedling in second year: *St*, stereome strands outside secondary leptome (*L*); *Camb*, cambium; *H*, hadrome; *PR*, parenchymatic ray; *P*, pith; × 320.

Juglans nigra

FIG. 10.—Staminate flower, seen from outside; stamens removed.

FIG. 11.—Two stamens, side and front view.

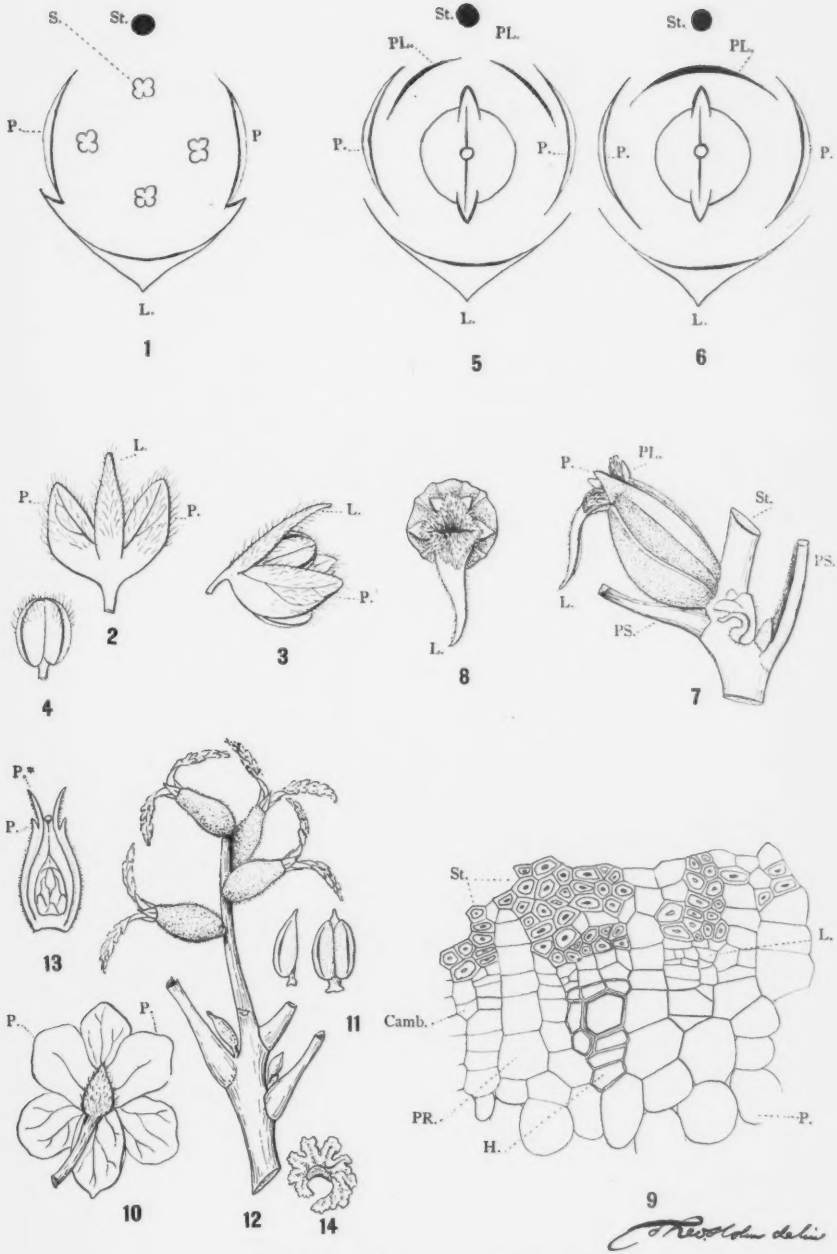
FIG. 12.—Branch with pistillate flowers; natural size.

FIG. 13.—Longitudinal section of pistillate flower; P^+, perianth leaves.

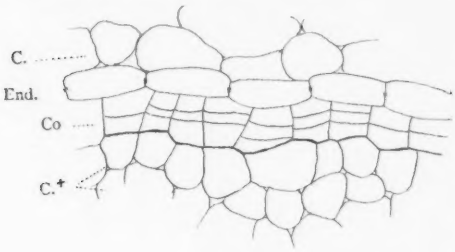
FIG. 14.—Cross-section of stigma.

[13] FOXWORTHY, E. W., Discoid pith in woody plants. Proc. Indiana Acad. Sci. p. 191. 1903.

[14] HOLM, THEO., Medicinal plants of North America. 9. *Phytolacca decandra* L. Merck's Report. p. 312. 1907.



HOLM on CARYA and JUGLANS



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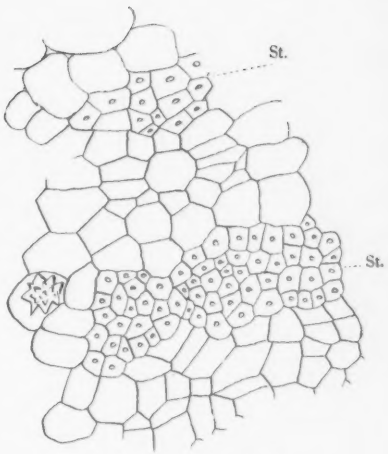

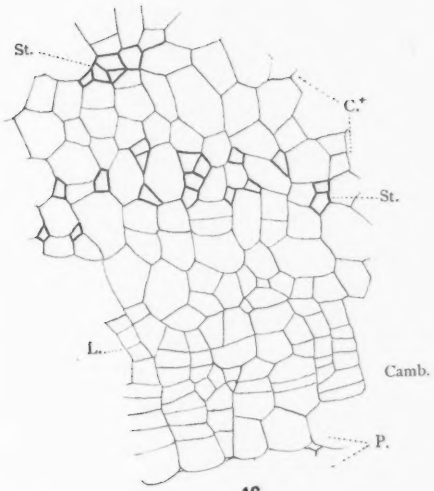

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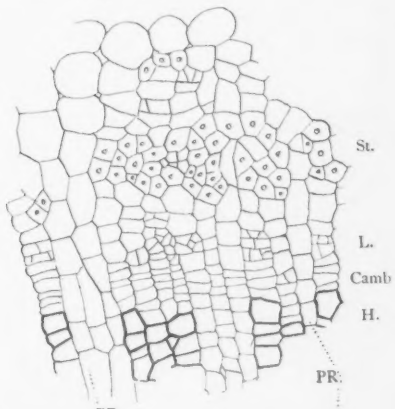

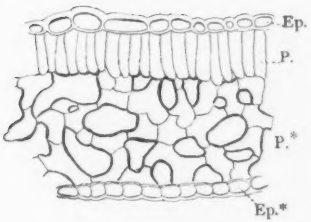

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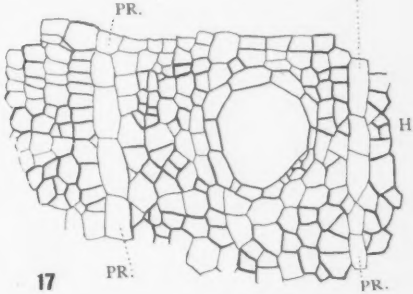

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HOLM on CARYA and JUGLANS

PLATE XVI

Juglans nigra

FIG. 15.—Cross-section of primary root of young seedling a month old: *C*, inner part of primary cortex; *End*, endodermis; *Co*, pericambial cork; *C+*, peripheral part of secondary cortex; × 320.

FIG. 16.—Inner part of same root (fig. 15): *C+*, secondary cortex with strands of stereome (*St*); *L*, leptome; *Camb*, cambium; *P*, outermost layer of pith; ×320.

FIG. 17.—Three cross-sections of old lateral root; *PR*, parenchymatic ray; ×320.

FIG. 18.—Cross-section of leaf: *Ep*, ventral, *Ep+*, dorsal epidermis; *P*, palisade tissue; *P+*, pneumatic tissue; ×320.

PHYLOGENETIC POSITION OF THE BACTERIA[1]

HILDA HEMPL HELLER

The subject of the phylogenetic position of the bacteria has been approached by many students. Early workers came to no more diverse conclusions than do modern ones. Some investigators, for example NÄGELI (24) and GÖTSCHLICH (14), have placed the bacteria with the fungi, while COHN (9), MIGULA (22), and SACHS (26) placed them with the algae. The early workers who assigned the bacteria to the fungi did so because both fungi and bacteria lack chlorophyll, and may thus be regarded as similarly degenerate algae, and because there are genera such as *Corynebacterium*, *Actinomyces*, *Streptothrix*, and *Oidium*, that may well be regarded as transitional forms. Classifiers of the fungi have not sufficiently emphasized the fact that in a group where chlorophyll is absent there is no compelling reason for presuming that the simpler forms, the bacteria, were descended from the higher ones, as the workers thought who considered them as directly descended from the algae. Even DE BARY (1), although he uses NÄGELI'S name "Schizomycetes" (fission fungi) for the bacteria, insists that they are not fungi, nor closely related to or descended from fungi.

The reason for classing the bacteria as a subordinate group of the algae has usually been the exceedingly close morphological resemblance of the higher bacteria to the blue-green algae (Cyanophyceae or Myxophyceae). COHN was the first to emphasize the relationship between these groups. The Cyanophyceae were long thought to be the most simple autotrophic forms. More modern systematists have separated the blue-green algae from those with sexual reproduction, and have united them with the bacteria. Thus ENGLER (12), in his second phylum Schizophyta, included only the two classes Schizomycetes and Schizophyceae; WARMING (28) made a similar division of his class Schizophyta; while BESSEY (3) in his phylum Myxophyceae, class Archiplastideae

[1] From the George Williams Hooper Foundation for Medical Research, University of California Medical School, San Francisco.

(blue-green algae without nuclear membrane), placed the Bacteriales as an order coordinate with two orders of the blue-green algae. BÜTSCHLI (6) and KLEBS (19) emphasized the common characters of the bacteria and the protozoa.

Today the question is apparently no nearer a solution than it was forty years ago. The various views are based on the consideration of different life manifestations. Close relationship between bacteria and protozoa, however, is no longer emphasized. The principal views held today are three: (1) that the bacteria are members of the group of fungi, (2) that they are derived from or closely related to the Cyanophyceae, and (3) that they are the primitive forms from which fungi and algae are derived. The first two opinions are held by morphologists. Those who have regarded the manner of division and sporulation, the external characters of the organism so to speak, and those who hold that bacteria possess a small oval or round nucleus, have allied the bacteria with the fungi. Others who have studied their nuclear structure have allied them with the Cyanophyceae. Chemists and general students of evolution have recently considered them as ancestors of the other groups.

The morphological field has been reviewed carefully by MEYER (21), who holds that the closest affinities of the bacteria are with the fungi. The bacterial nucleus, according to his conception, is similar to the nucleus of the fungi. SWELLENGREBEL (27), GARDNER (13), and DOBELL (11) have observed structures, which they believe to be nuclei, that have marked resemblance to the chromophyll portion of the central bodies of the Cyanophyceae. GUILLIERMOND (15) and a number of other workers hold the bacterial nucleus to be "chromidial" or finely distributed in the cytoplasm. DOBELL finds structures resembling all these types, which he holds to be nuclei, and he believes the bacteria to be related most closely to the Cyanophyceae. WEST (29) described a blue-green alga, *Myxobactron*, which shows no differentiation of its protoplasm. PARAVICINI (25) has recently described minute compact structures that he believes to be nuclei.

JENSEN (18) rearranged the bacteria on a chemical basis, and defined their relation to the algae, fungi, and protozoa, presuming

that the earth was dark when life began, and that chlorophyll-free bacteria, probably those capable of oxidizing methane, were the earliest forms of life with which we are familiar today. JENSEN derived the blue-green algae from the sulphur bacteria, the fungi from the oxidizing bacteria by way of the Actinomycetes, and the higher bacteria from the earliest nitrogen-reducing organisms. KLIGLER (**20**) was also of the opinion that bacteria may well have been the earliest forms of life, and he placed the methane-oxidizing type at the base of his tree. BREED, CONN, and BAKER (**4**) pointed out that there is no proof that the world was dark when life began; that in case it was light the ancestors of the blue-green algae or of the phototrophic pigment bacteria, which use sunlight to metabolize organic substances, may have been the most primitive forms; or that the most primitive form may be entirely unknown to us. Thus we see that because of the discovery of the existence of autotrophic bacteria the old question of the origin of the bacterial group is again open.

When the synthesis of inorganic substances into organic material was thought to be possible only by the aid of chlorophyll, the natural trend of evolutionary reasoning led to the derivation of other forms of life from simple chlorophyll-containing ones. Bacteria apparently are simpler than the most simple chlorophyll-bearing algae. They were therefore thought to be degenerate. Workers who saw in them affinities with the chlorophyll-free fungi were not careful to state what their relationship with the fungi really might have been. The reader is usually left with the impression that they are in an intermediate position or related to the higher fungi. MEYER, who excluded the *Thiobacteria*, *Chlamydobacteria*, and *Myxobacteria* from his Eubacteria or bacteria proper, placed his group as the second class of the Eumycetes next to the Phycomycetes or algal fungi. CLAYPOLE (**7**) considered both bacteria and fungi to be derived from the leptothrix-tuberculosis group.

A rather suprising paper has recently appeared by BERGSTRAND (**2**), who has observed the budding and branching of *Corynebacterium* and other forms, and believes that the bacteria are closely related to the fungi. Budding and binary fission are not so different in their nature that they should be considered very important

characters. One genus of yeasts, the *Schizosaccharomyces*, divide as do the bacteria. Apparently typhoid bacilli may either bud or divide by fission HORT (16). Upon this one character of budding, BERGSTRAND lays so much emphasis that he refuses to consider other characters, also morphological, which show similarity between the bacteria and other forms: "To discuss further the eventual relationship of Cyanophyceae to bacteria does not seem necessary, because any such theory would appear false at the moment that it became clear that bacteria are more closely related to fungi, as I shall show." It must be noted that, like MEYER, BERGSTRAND excludes from his bacterial group the higher bacteria which do not resemble the fungi as much as they do the algae. One would be equally justified in naming as bacteria all the chlorophyll-free rods except the branching and budding ones. BERGSTRAND defines the bacteria as Fungi Imperfecti. The Fungi Imperfecti are an entirely artificial group comprising fungi that have not developed sexual characters, those that have lost such characters, and those that have not been studied sufficiently to determine their true relationships. BERGSTRAND concludes that bacteria are to be regarded as Fungi Imperfecti that have developed through the reduction of higher forms, and not as lowly primordial organisms to be placed at the very beginning of the organic world. An example of his logic is as follows: "Of course if one regards bacteria as Fungi Imperfecti one cannot accept the theory that the chromatin is spread diffusely in the cell body, because this assumes it would seem a much lower developmental stage."

It is not the intention of this paper to criticize workers for connecting bacteria with fungi because of morphologic relationships between the two groups. BERGSTRAND'S observations serve to strengthen the tie between the fungi and the bacteria, but the lightness with which he proposes the degeneracy of the latter forms from the former is a novel process to comparative biological reasoning. The trend of evolution is rarely in the direction of degeneracy. Degeneracy occurs as a consequence of a parasitic habit or because of abundant food supply. It is usually accompanied by vestigial traces of a former complexity. The characters which the bacteria and fungi have in common are not manifestly vestigial in the

bacteria. The supposed loss of sexual characters among the fungi has been attributed to their change from water forms to air forms, but bacteria are not air forms. The theory of the degeneration of the bacteria from the algae was a very peculiar one, imposed by ignorance of certain primitive bacteria. It is now known that bacteria exist which are autotrophic and can secure growth energy from inorganic carbon, so that their lack of chlorophyll is no longer a reason for considering them degenerated from the chlorophyll-containing forms. The existence of autotrophic fungi, to my knowledge, has never been demonstrated.

There is a simple group, therefore, the members of which are autotrophic; and two diverse complex groups, one of which (the fungi) is not autotrophic and may not be homogeneous. Both of these complex groups show marked resemblances to the simple one. JENSEN'S scheme, which derives both of them from the simple one, is not to be lightly thrown aside. It coincides too well with the general scheme of evolution. We may, if we wish, consider the question entirely open, but nomenclature and classification should be so formulated that they do not deliberately mislead the amateur on the subject of these relationships. Formerly the tendency in botanical classification was to make a treelike structure, throwing groups together that had but superficial resemblances, but classifiers today are more prone to refuse to indicate relationships where descent is not fairly certain, and to group the plants in phyla like the zoological phyla, whose connections may or may not be understood.

The bacteria, fungi, and blue-green algae, therefore, may be all in one phylum, or may be placed in three separate phyla, but to place the bacteria with either fungi or Cyanophyceae is inconsistent, because it leaves out of consideration the third group which may be equally related to the bacteria. Probably the trend of classification would favor the separation of these groups into three separate phyla, for to place the fungi and Cyanophyceae together is rather stretching the limits of the botanist's conception of a phylum. Moreover, in view of the existing divergent opinions, a classification that does not commit one on the subject of these relationships is preferable. A name for the phylum that is to

contain the bacteria only should not indicate for them a subordinate position in another group as does the name "Schizomycetes," proposed by NÄGELI (**23**) in 1857 for a mongrel group which contained bacteria, sporozoa, and oscillaria, a group whose affinities he hesitated to suggest. The connotation of this term has always been "fission fungi," and its German form "Spaltpilze" has been widely used. And yet BUCHANAN (**5**) finds it entirely appropriate and valid and proceeds to place his Schizomycetes with the Cyanophyceae. Article 51, division 4, of the Vienna rules (**17**) considers the name Schizomycetes as invalid. "Everyone should refuse to admit a name . . . . when the group which it designates embraces elements altogether incoherent, or when it becomes a permanent source of confusion and error."

We should choose for the bacterial phylum a name that will immediately be understood by the non-professional worker. Names like *Phytozoidia* Perty of course are objectionable. *Vibrio* Ehrenberg probably included certain infusoria as well as bacteria. *Vibrionia* Cohn did not include forms later studied by that author. *Bacteria* Cohn (**8**) probably included all the forms that we today call bacteria except *Beggiatoa*, and it did not include members of other groups. As the Committee of the Society of American Bacteriologists (**10**) places 1880 as the date at which considerations of priority are to commence, we are free to choose from among these names. Bacteria implies no relationship to other groups. It is otherwise highly suitable because it is understood by laymen and is short and euphonious. The following was COHN's conception of the group: "Die Bacterien sind chlorophyllose Zellen von kugeliger, oblonger oder cylindrischer, mitunter gedrehter oder gekrümmter Gestalt, welche ausschliesslich durch Querteilung sich vermehren, und entweder isoliert oder in Zellfamilien vegetieren."

In consideration of the fact that no relationship of the bacteria to other groups has been generally accepted the following phylum is proposed:

BACTERIA (nov. phyl.).—Simple one-celled plants that multiply typically by binary fission and occasionally by budding. They show no form of sexual multiplication. They rarely contain cellulose and do not contain chlorophyll or phycocyanin.

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LITERATURE CITED

1. DE BARY, A., Comparative morphology and biology of the fungi, mycetozoa, and bacteria. Strassburg, 1884; Oxford, 1887.
2. BERGSTRAND, H., The nature of bacteria. Jour. Infec. Diseases **27**: 1–22. 1920.
3. BESSEY, C. E., The plant phyla. 1912.
4. BREED, R. S., CONN, H. J., and BAKER, J. C., Comments on the evolution and classification of the bacteria. Jour. Bacteriol. **3**:445–459. 1918.
5. BUCHANAN, R. E., Studies in the nomenclature and classification of the bacteria. II. Jour. Bacteriol. **2**:155–164. 1917.
6. BÜTSCHLI, O., Quoted from A. Meyer[21].
7. CLAYPOLE, E. J., On the classification of the streptothrices, particularly in their relation to bacteria. Jour. Exper. Med. **17**:99–116. 1913.
8. COHN, F., Untersuchungen über Bakterien. Biologie der Pflanzen **1**:127. 1872; quoted from MIGULA, System der Bakterien **1**:17. 1897.
9. ———, Untersuchungen über Bakterien. II. Beiträge zur Biologie der Pflanzen **1**: 1875; quoted from MIGULA, System der Bakterien **1**:19. 1897.
10. Final Rep. Com. Soc. Amer. Bacteriologists on characterization and classification of bacterial types, the families and genera of the bacteria. Jour. Bacteriol. **5**:191. 1920; prelim. Rep. *ibid.* **2**:505–66. 1917.
11. DOBELL, C. C., Contributions to the cytology of the bacteria. Quart. Jour. Micr. Sci. N.S. **56**:395–506. *pls. 4.* 1911.
12. ENGLER, A., Syllabus der Pflanzenfamilien. 1907.
13. GARDNER, N. L., Cytological studies in Cyanophyceae. Univ. Calif. Publ. Bot. 1906.
14. GÖTSCHLICH, "Einleitung" of FLÜGGE'S Mikroorganismen. 1896.
15. GUILLIERMOND, A., Quoted by A. MEYER[21].
16. HORT, E. C., The life history of bacteria. Brit. Med. Jour. **1**:571–575. *pls. 3.* 1917.
17. Trans. Internat. Bot. Congress, Vienna, 1905.
18. JENSEN, ORLA, Die Hauptlinien des natürlichen Bakteriensystems. Centralbl. Bakteriol. Abt. II. **22**:305–346. 1909.
19. KLEBS, G., Quoted by A. MEYER[21].
20. KLIGLER, I. J., The evolution and relationships of the great groups of bacteria. Jour. Bacteriol. **2**:165–176. 1917.
21. MEYER, A., Die Zelle der Bakterien. 1912.
22. MIGULA, W., In WARMING'S Systematic Botany, Engl. Transl. p. 26. 1904.
23. NÄGELI, O., Amtlicher Bericht über die 33 Versammlung Deutscher Naturforscher und Aertzte zu Bonn, p. 133, 1857 (1859), quoted from MIGULA, System der Bakterien **1**:9. 1897.
24. ———, Die niederen Pilze in ihren Beziehungen zu den Infektionskrankheiten. 1877; quoted from MANGIN, Bacteria. 1884.
25. PARAVICINI, E., Zur Frage des Zellkernes der Bakterien. Centralbl. Bakt. Abt. II. **48**:337–340. 1917–1918.
26. SACHS, J., Quoted from STERNBERG, Textbook of bacteriology. 1901.
27. SWELLENGREBEL, N. H., Untersuchungen über die Zytologie einiger Fadenbakterien. Arch. Hyg. **70**:380–403. *pls. 2.* 1909.
28. WARMING, E., Systematic botany. Engl. Transl. p. 22. 1904.
29. WEST, W., Fresh water algae of the Percy Sladden Memorial Expedition in South West Africa. Ann. So. African Mus. **9**: 1912; quoted from WEST, Algae. 1916.

ODONTOPTERIS GENUINA IN RHODE ISLAND

EDA M. ROUND

(WITH FIVE FIGURES)

One of the most characteristic and common fossils of Rhode Island is *Odontopteris genuina* Grand'Eury. These plants apparently grew to great size around the coal swamps of the Narragansett Basin during the Carboniferous, somewhat like the tree ferns of the tropical forests of the present day (fig. 1). The fronds appear to have been bifurcate, the angle formed by the branches being about 90° (fig. 2). The rachis is striated and clothed with short pinnae, the latter having enlarged pinnules at their tips and being more separated than those of the expanded parts of the frond. The pinnae vary considerably, sometimes being short or at other times attaining a length of over 15 cm. The pinnules often vary in shape on the same specimen, some being falcate and acute, while others are oval and rounded at their apices. The acute type of *O. genuina* is very common in the state, and may have come about as a result of the conditions under which the fossils were originally imbedded. The pinnules appear to have been firm in texture and convex or "bombe" in shape. If these shapes were squarely imbedded they would appear oval (fig. 3*a*) when fossilized, while more pointed effects would result from preservation at a slight angle (fig. 3*b*; fig. 4*a*, *b*), and long, narrow effects from still greater angles (fig. 5*a*). While these forms have pinnules 3–8 mm. broad by 10–16 mm. long, the illustrations from Pawtucket show much larger sizes and resemble those figured by ZEILLER[1] from Commentry, France. The Pawtucket specimens do not appear to have been as firm and thick as the smaller Rhode Island types, and the borders are inclined to be less even. The pinnules also were evidently flat rather than convex in shape and somewhat cyclopterid in appearance (fig. 3*c*, *d*; fig. 5*b*).

[1] ZEILLER, C. R., Études sur le Terrain Houiller de Commentry. *pl. 24.* 1888.

It appears that *O. genuina* has frequently been listed among Rhode Island fossils under the name *O. brardii* Brgt., presumably

FIG. 1.—*Odontopteris genuina:* tip of frond (distorted); reduced ½.

owing to the numerous examples of falcate forms in evidence. A careful study of the veining upon good material, however,

reveals a much more complex system than that of *O. brardii*.[2] In general the *O. genuina* has a thin medial nerve, distinct almost to the apex, while the lateral veins spread at very acute angles

FIG. 2.—*Odontopteris genuina:* mode of branching; reduced ½.

and fork in passing to the border one to four times, the lowest or outermost only coming from the rachis. Typical *O. brardii*, on the other hand, is described as having veins all of which come

[2] BRONGNIART, A., Histoire des végétaux fossiles. *pls. 75, 76.* 1828.

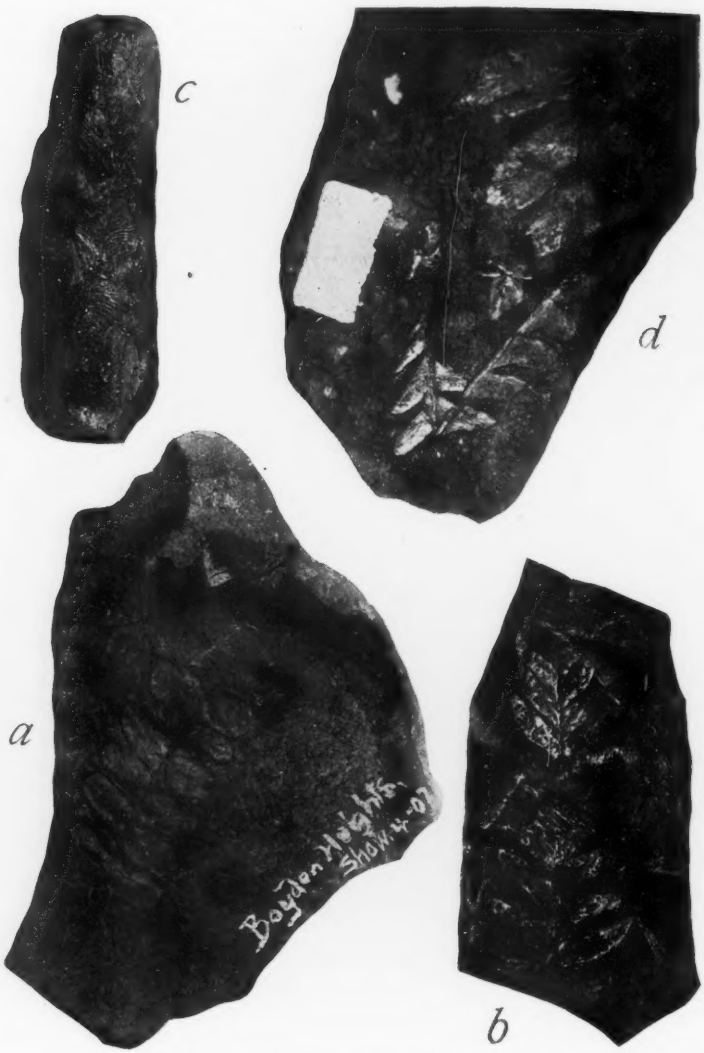

FIG. 3.—*Odontopteris genuina:* slightly reduced.

FIG. 4.—*Odontopteris genuina: a*, natural size; *b*, ×2.

from the rachis, a condition which the writer has never observed in Rhode Island specimens.

FIG. 5.—*Odontopteris genuina:* natural size.

Odontopteris genuina has been found in eight localities in the state, namely, Portsmouth, Boyden Heights, The Tunnel, Provi-

dence, Pawtucket, Arlington, Cranston, and Warwick. These rocks are now in the collection of the geological department of Brown University. As they never appear waterworn it may be inferred that these plants fringed the coal marshes of the Narragansett Basin in the Carboniferous, and were buried and fossilized near their places of growth. Most of these fossiliferous materials are preserved in fine grained black shale. The specimen from Boyden Heights, however, is of sandstone, a material not generally fossiliferous in the state except as the matrix of coarse forms like Calamites (fig. 3*a*).

With such abundance of preserved material as is represented by *O. genuina* in Rhode Island, it seems significant that no fruited pinnae are in evidence. It has been proved by KIDSTON,[3] however, that many of the so-called fossil "ferns" were really Pteridosperms or Cycadofilicales. Many detached seeds are found in the rocks of Rhode Island, proof that the ancestors of modern flowering plants were denisons of the coal forests of the state, among which it seems probable that *O. genuina* may sometime be included.

[3] KIDSTON, R., Les végétaux houillers recueillis dans le Hainaut belge. Mém. Mus. Roy. Hist. Nat. Belg. 4:5. 1911.

BRIEFER ARTICLES

ROOT DEVELOPMENT OF WHEAT SEEDLINGS

(WITH ONE FIGURE)

In a study of the salt requirements of wheat in water cultures, certain conditions under which wheat seedlings developed relatively large root systems were noted. Wheat seedlings with shoots 8–10 cm. high and roots 10–12 cm. long were set out according to the usual method employed for solution culture experiments, in two quart Mason jars filled with tap water from the laboratory. The cultures were allowed to grow for six weeks at a temperature range of 22–32°C. and without renewal of the tap water. At the end of this period the tops of the cultures had grown about 12–16 cm. high (having gained from 2 to 4 cm.) and the root mass measured 70–80 cm. in length. In some cultures, however, single roots had attained a length of over 100 cm. So far as the total dry weight of these cultures was concerned, it may be stated that about one-half was contained in the roots.

It was at first thought that the relatively low total salt concentration of the tap water was responsible for the results. The tap water of the laboratory contained a total salt concentration whose osmotic value was calculated to be approximately equal to 0.1 atmosphere pressure. To test this supposition as being the cause for the extraordinary long root growth of the wheat seedlings, several different kinds of complete nutrient solutions were prepared, each having a total salt concentration giving an osmotic value equal to about 0.1 atmosphere pressure, and these were used as the culture media for wheat. These dilute solutions, which contained all of the chemical constituents essential for plant growth, proved to be relatively poor media for the root development of wheat seedlings. Another set of tests, however, with solutions of the same salts and salt proportions as those of these dilute solutions but of greater total concentration (0.5 atmosphere), proved to be very good media for the root development of wheat seedlings. These results suggested that it might be the absence or the deficiency of an element in the tap water that was responsible for the results. Tests were then made using nutrient solutions of a total salt concentration equal to give about 0.5 atmosphere osmotic pressure, but modified so as to omit one

of the elements considered essential for normal plant growth. Wheat seedlings with shoots 8–10 cm. high and roots 10–12 cm. long were placed in these different nutrient solutions. After the cultures had grown five weeks it was found that the set grown in solutions that lacked nitrogen had developed a root system similar and equal in length to those obtained from cultures grown in tap water. The tops of the plants grown in the relatively nitrogen-free solutions gained only a few centimeters in shoot length, but the root mass had attained a length of 60–70 cm. for the different cultures of the set. From these results it was concluded that stimulation of long root development of wheat seedlings grown in tap water was related to the deficiency of nitrogen in that growth medium.

FIG. 1.—Culture to left grown in tap water for six weeks; culture to right grown in good nutrient solution for two weeks.

Two questions might be asked in reference to the results obtained: (1) Can plant roots grow without nitrogen? (2) What constitutes the best root development of a wheat plant for its normal growth? As to the first question, the tests did not prove that the large root development obtained from wheat seedlings grown in tap water or in the prepared nitrogen-free solutions was due to the total absence of nitrogen, or that it would have been obtained in the total absence of nitrogen. Obviously some nitrogen was contained in the seedlings when they were set in these media. Presumably less and less became available to the growing roots as the plants grew older, however, as the small supply originally in the seed had to suffice for more and more tissue (chiefly roots) as the seedlings enlarged. Whether the supply was ever exhausted in the growing region of the roots is not known.

An answer to the second question must also be given as a hypothesis. The large root development of the wheat seedlings placed in tap water did not result in the production of large wheat plants. The roots grew at the expense of the tops. Obviously wheat shoots could not have grown to any appreciable extent without roots, so between the two limits thus indicated (no roots on the one hand, and one-half of the total dry matter being roots on the other hand) must be found that relation of root to top that will bring about the best growth of the wheat plant.

Fig. 1 shows the relative root development of two different cultures, with approximately similar top growth. One was grown in tap water for six weeks and produced roots over 100 cm. long, the root mass being about six times longer than the length of the tops. The other culture was grown in a good nutrient solution for two weeks and produced roots that were only a trifle longer than the length of the tops. Approximately this same ratio of length of root to that of top would have been maintained if it had been grown six weeks or longer in this good nutrient solution.—W. F. GERICKE, *Division of Soil Chemistry and Bacteriology, University of California.*

CURRENT LITERATURE

BOOK REVIEWS

Ecological plant geography

The name of WARMING always comes first to mind when one thinks of the great names in modern ecology. In November 1921 he passed his eightieth milestone, receiving a portrait album together with the congratulations of his coworkers in all lands. Ten years ago he retired from active service at the University of Copenhagen, but these ten years have been full of important researches, and his publications during this period have been numerous. One of the most important of these publications is the third German edition of his ecological plant geography.[1] The first German edition appeared in 1896, being essentially an unmodified translation by KNOBLAUCH of the original Danish edition of 1895. The second German edition was issued by GRAEBNER without cooperation with WARMING. The English edition of 1909 was essentially a new book, with a very different grouping of the subject matter, in which the author was materially assisted by a young Danish geographer, MARTIN VAHL. The third German edition has been worked over very carefully by WARMING, although it follows the general features of the English edition. The most conspicuous changes are seen in the chapter that deals with formations and associations, and here the author follows the recommendations of the Brussels Congress of 1910. The book is also much larger than preceding editions, and the references to the literature are brought to date, so far as possible. But for the war, the book would have appeared much sooner than it did. It was asked for by the publishers in 1912, and was ready in 1914.—H. C. COWLES.

Principes de Biologie Vegetale

Following his volume on *L'Evolution des Plantes*, published in 1918, the second posthumous volume of BERNARD'S[2] lecture notes has been published under the title *Principes de Biologie vegetale*. The first part deals with cellular physiology of plants, with chapters on the principle of determinism, physical conditions of nutrition, nutritive metabolism, carbon nutrition, nitrogen nutrition, and the action of exterior agents upon the living cell. The second part of

[1] WARMING, EUG., and GRAEBNER, P., EUG. WARMING'S Lehrbuch der ökologischen Pflanzengeographie; dritte umgearbeitete Auflage. pp. 762. Berlin: Gebrüder Borntraeger. 1918.

[2] BERNARD, NOEL, Principes de Biologie vegetale. pp. xii+212. *figs. 18*. Paris: Felix Alcan Library. 1921.

the volume is entitled coordination, and contains chapters on Thallophytes and Schizophytes, Myxomycetes and fungi, algae, lichens, and a final chapter on immunity among plants. It is an elementary treatise, written in entertaining and lucid style. That the author has been dead ten years accounts for the appearance of occasional remarks which do not quite reflect our latest knowledge, as for instance, that "the formula for the constitution of chlorophyll is not known." Beginners, either in botany or French, would find it a delightful little volume.—C. A. SHULL.

MINOR NOTICES

Flora of Natal.—BEWS,[3] well known for his ecological study of the vegetation of Natal, has published a taxonomic account of the flora "for the purpose of assisting the study of plant ecology and botanical survey work in Natal." The introduction contains a very interesting account of the history of botany in Natal, from the earliest collector (1832) to the present time. The analytical keys are remarkably simple, leading to the genera, but the species are merely listed, with their ecological range and often with their local Zulu names. The author states that "the flowering plants of Natal, as now arranged, belong to 148 families, and include 901 genera and 3786 species."—J. M. C.

Osmotic pressure.—The publication of a new edition of Pfeffer's[4] famous work on osmotic pressure will be welcomed by students of plant physiology and physical chemistry who have desired to own a copy of this classic work. No changes have been made from the first edition, except that an introductory appreciation of PFEFFER'S work by CZAPEK precedes the text.—C. A. SHULL.

NOTES FOR STUDENTS

Specificity of chromosomes and sex-determination.—For a final proof of the rôle of the individual chromosome we must look to the remarkable investigations of BRIDGES.[5] It was this author who furnished a direct demonstration of the chromosome theory of heredity, when he showed that irregular distributions of the sex chromosomes of *Drosophila* were accompanied by irregularities in the inheritance of known sex-linked factors. He now[6] provides a similar demonstration of the specificity of the autosomes, and at the

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[3] BEWS, J. W., The flora of Natal and Zululand. pp. vi+248. Pietermaritzburg. 1921. 15*s*. (Whelden and Wesley, 28 Essex St., Strand, London).

[4] PFEFFER, W., Osmotische Untersuchungen. pp. xiv+236. *figs. 5*. Leipzig: Engelmann. 1921.

[5] BRIDGES, C. B., Non-disjunction as proof of the chromosome theory of heredity. Genetics 1:1–52. 1916.

[6] ———, Triploid intersexes in *Drosophila melanogaster*. Science **54**:252–254. 1921.

same time adds a very significant and far-reaching modification of present ideas on sex determination.

An unexpected distribution in inheritance of known factors which are located on the second and third chromosomes of *Drosophila* was explainable on the assumption that the female parent of the cross was a triploid with respect to these chromosomes. Cytological examination proved that this was actually the case. This same group of flies also exhibited some remarkable irregularities in their sex condition. A considerable group of "intersexes" occurred, as evidenced by the secondary sex characters and the condition of the gonads as well. This was apparently a bimodal group, some of the intersexes being of a more "female type" and others of a more "male type." Cytological examination of these individuals revealed that the second and third chromosomes were regularly present in a triploid condition, that the fourth chromosome was either diploid or triploid, and that two x-chromosomes were regularly present (with or without a y-chromosome). The situation is interpreted as follows. "It is not the simple possession of two x-chromosomes that makes a female, or of one that makes a male. A preponderance of genes that are in the autosomes tends toward the production of male characters; and the net effect of genes in the x is a tendency to the production of female characters. The ratio of *2x:2 sets autosomes* produces a female, while *1x:2 sets autosomes* produces a male. An intermediate ratio, *2x:3 sets autosomes*, produces an intermediate condition, the intersex. The fourth chromosome seems to have a disproportionately large share of the total male-producing genes; for there are indications that the triplo-fourth intersexes are preponderantly of the 'male type', while the diplo-fourth intersexes are mainly 'female type.'" According to this conception, *3x:2 sets autosomes* should be "superfemales," and *1x:3 sets autosomes* "supermales." The author has actually identified such types, both being sterile.

It is certain that this conception will exert a far-reaching influence upon the existing ideas of sex-determination. In the first place, it gives a somewhat more exact idea as to the elements effective in determining sex. Hitherto it has been thought, rather vaguely, that the x-chromosome determines sex either per se or by virtue of some special factor which it contains. It is interesting to realize that a number of factors may be influencing sex in one direction or the other, and perhaps that these are identical with factors which have previously been known as playing another rôle. A different rate of metabolism has commonly been associated with the two sexes; a study of the influence of specific factors on metabolic rate now becomes significant in this connection. In the second place, it furnishes an exact interpretation of intersexes on a chromosome basis. Hitherto intersexes have either been interpreted in very vague terms, or have been used as an argument against the chromosome theory of sex determination, or have been harmonized with the sex chromosome theory only by the assumption of some additional extrachromosomal influence (GOLDSCHMIDT). The present conception paints a quantitative picture of sex

without calling upon any other effective elements than the "orthodox" factors of inheritance that are located on the chromosomes. In the third place, the theoretical possibility of artificially controlling sex is illuminated. Such control should be possible to the degree that the ordinary heritable characters can be successfully duplicated artificially. The fact that the fourth chromosome (which is known to contain relatively few factors) is preponderant in its influence toward maleness suggests that a few specific factors may be preponderant in influence. Artificial control, therefore, should necessitate the duplication of the effects of only a few of the factors. Also, the identification of particularly effective heritable factors should be followed by the establishment of a race with a heritably distorted sex ratio.—M. C. COULTER.

Taxonomic notes.—BØRGESEN,[7] in continuation of his studies of the marine algae of the Danish West Indies, has completed the Rhodophyceae. These two concluding parts include 101 species, four of which are new, distributed among 29 genera. The following three new genera are established: *Cottoniella*, *Coelothrix*, and *Hypneocolax*. An extensive appendix (86 pp.) gives a list of the Chlorophyceae, Phaeophyceae, and Rhodophyceae found at the islands, together with addenda and corrections.

ENGLER[8] and his collaborators, in continuation of their studies of the African flora, have published the following results: ULBRICH describes 4 new species of *Pavonia;* MEZ describes 94 new species of grasses, 33 in *Panicum*, 33 in *Melinis*, and 18 in *Digitaria;* ENGLER describes 16 new species of Gesneraceae, 14 of which are in *Streptocarpus*, and also establishes a new genus (*Ctenocladus*) of Moraceae; WOLFF describes 19 new species of Umbelliferae and establishes *Caucaliopsis* as a new genus; KRAUSE describes 8 new species of Liliaceae; IRMSCHER describes 7 new species of Begoniaceae; and BITTER, in continuation of his monograph of African *Solanum*, has reached 56 species.

RYDBERG[9], in continuation of his work on the Rosaceae, has presented the roses of the Columbia region, which includes Oregon and Washington, together with British Columbia and northern Idaho. In this region he recognizes 37 species of *Rosa* and nine hybrids.

SCHLECHTER,[10] in reorganizing the classification of *Spiranthes*, recognizes 35 species of *Spiranthes* and establishes 16 new genera as follows, chiefly from Mexico, the West Indies, and South America: *Galeottiella*, *Hapalorchis*,

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[7] BØRGESEN, F., The marine algae of the Danish West Indies. Rhodophyceae (5 and 6). Dansk Botanisk Arkiv **3**: 305–498. *figs. 308–435*. 1919 and 1920.

[8] ENGLER, A., Beiträge zur Flora von Afrika. XLVIII. Bot. Jahrb. **75**: 161–301. 1921.

[9] RYDBERG, PER AXEL, Notes on Rosaceae. XIII. Bull. Torr Bot. Club **48**: 159–172. 1921.

[10] SCHLECHTER, R., Versuch einer systematischen Neuordnung der Spiranthinae. Beih. Bot. Centralbl. **37**: 317–454. 1920.

Beloglottis, *Mesadenus*, *Pseudogoodyera*, *Brachystele*, *Schiedeella*, *Trachelosiphon*, *Deiregyne*, *Gamosepalum*, *Funkiella*, *Cladobium*, *Coccineorchis*, *Lyroglossa*, *Pteroglossa*, and *Centrogenium*.

STAPF[11] has established a new genus (*Daturicarpa*) of Apocynaceae from the Belgian Congo. It belongs to the Tabernaemontaneae, and includes three species of shrubs.—J. M. C.

Classification of symbiotic phenomena.—MCDOUGALL[12] has written a very sensible and stimulating article on symbiosis and its subdivisions. Very properly he disapproves of the numerous restricted definitions of the term, going back to the original definition of DEBARY, which happens also to be the only definition that justifies the retention of the word in the literature, and the only definition that is etymologically correct. It is one of the curiosities of biological science that so many writers have used the term symbiosis in the sense of mutualism, a relationship that does not exist; and even if it did exist we should not need two terms for the same relationship. The term is much needed, however, in the original and correct sense of "the living together of dissimilar organisms," as pointed out by MCDOUGALL, for there is no other term of such broad and general nature. The author's primary division of symbiosis is into disjunctive and conjunctive, each in turn being subdivided into social and nutritive; each type of nutritive symbiosis may be further subdivided into antagonistic and reciprocal. Plant communities illustrate social disjunctive symbiosis; lianas and epiphytes illustrate social conjunctive symbiosis. Antagonistic disjunctive symbiosis is illustrated by herbivores and plants; antagonistic conjunctive symbiosis is illustrated by the ordinary cases of parasitism, such as plant diseases, ectotrophic mycorhizas, etc. Reciprocal disjunctive symbiosis is illustrated by flowers and pollinating insects, reciprocal conjunctive symbiosis by cases of reciprocal parasitism, such as are seen in lichens, root tubercles, and endotrophic mycorhizas. MCDOUGALL condemns the curious view of some botanists that lichens are simply fungi. He asserts that it is just as absurd to call a fungus-alga combination a fungus as it would be to apply the term fungus to the mycorhizal combination of roots and fungi.—H. C. COWLES.

Forests of British Columbia,—WHITFORD and CRAIG have published an admirable volume on the forests of British Columbia, which are among the most interesting forests in existence.[13] The report is based on three years of

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[11] STAPF, O., *Daturicarpa*, a new genus of Apocynaceae. Kew Bull. no. 4. 166–171. *figs. 2.* 1921.

[12] MCDOUGALL, W. B., The classification of symbiotic phenomena. Plant World **21**:250–256. 1918.

[13] WHITFORD, H. N., and CRAIG., R. D., Forests of British Columbia. Rept. Comm. Conserv. Canada, Committee on Forests. pp. 409. *pls. 28. maps 21.* Ottawa. 1918.

careful study, and it forms one of the most satisfactory volumes dealing with forest resources that has come to our attention. The forests of British Columbia are much more important economically than those of any other province; indeed it is thought that the lumber resources of British Columbia are equal to the combined lumber resources of the other provinces. The province has an area of about 356,000 square miles, of which more than half (200,000 square miles) is unsuited to the production of merchantable timber, chiefly because of altitude. Of the 156,000 square miles that might produce timber, 100,000 have been ruined by fire. As a matter of fact the land now clothed with merchantable timber amounts to only 28,000 square miles. Since most of the forest land is non-agricultural, a strong plea is put forth for reforestation. The chapters in Part I deal respectively with geographical relations, physiographic relations, climatic and soil relations, land tenure, forest administration, forest policy, forest exploitation, forest trees, and insect injuries. The physiographic chapter brings out the fact that British Columbia is "a sea of mountains," and that the average altitude of the province is 3500 ft. above the sea. To the ecologist the most interesting chapters are the one on climatic and soil relations, in which are discussed the various forest types of the province, and the one on forest trees, giving a detailed account of each of the tree species. About half of the maps portray the distribution of individual species. The plates exhibit excellent photographic reproductions of forest types and scenes.—H. C. COWLES.

Montane flora of Burma.—In sketching the vegetation of the mountains of northeastern Burma, WARD[14] shows that a tropical rain forest of Indo-Malay forms, such as *Dipterocarpus*, *Shorea*, *Garcinia*, *Calamus*, and *Ficus*, is found up to an altitude of 5000 ft. From 5000 to 8000 ft. there is developed a temperate rain forest, with *Gordonia*, *Quercus*, *Magnolia*, *Acer*, and *Rhododendron* as characteristic species. Epiphytic mosses, ferns, and orchids abound, but lianas are few. There follows a conifer forest extending from 8000 to 12,000 ft., which shows its tropical relationship only by the presence of species of bamboo. *Abies* predominates, with some admixture of *Pseudotsuga*, *Pinus*, *Juniperus*, and *Larix*. *Rhododendron*, with over 50 species in the undergrowth and in the higher alpine scrub, *Ribes*, *Rubus*, *Rosa*, *Philadelphus*, *Deutzia*, and *Hydrangea* are among the most abundant shrubs.

An examination of the flora reveals an admixture of Himalayan, Indo-Malayan, Chinese, and endemic forms. This leads to the conclusion that this mountain barrier, marking the eastern limit of the Indo-Malayan region for 750 miles, has been connected in the north with the Himalayan ranges on the one hand, and with the great China divide on the other, linking them in a common center.—GEO. D. FULLER.

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[14] WARD, F. K., The distribution of floras in southeast Asia as affected by the Burma-Yunnan ranges. Jour. Ind. Bot. **2**:21–26. *pls. 2*. map. 1921.

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